WHITEPAPER

Demystifying Virtual Production

A Practical Guide to Virtual Production Workflows, Techniques, and Economics

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1 – Introduction

This whitepaper is intended for experienced studio executives, producers, directors, and other creatives who are familiar with traditional production techniques but are interested in learning more about Virtual Production (VP) and the new real-time workflows it enables. We are focused predominantly on narrative production work for movies and TV shows and the underlying workflows for them. We'll take a closer look at the budget, scheduling, and team impacts of Virtual Production during pre-production, production, and post-production and the implications of it all for a workflow.

"Virtual Production" has become an often used, frequently misunderstood, and sometimes inaccurately applied term. What was an emerging field with various new production technologies, each with predictable innovation cycles that were reaching maturity around the same time, was suddenly thrust into the spotlight due to the travel restrictions of a global pandemic and labelled as some sort of "panacea" that would replace many legacy technologies overnight. This attention to Virtual Production (or "VP" as we shall call it from here on out) was both a blessing (for the sudden investment and attention) and a curse (for the improbable expectations), and many thought VP was a fad conjured by COVID[1] and would soon disappear along with other dream technologies that didn't live up to the hype.
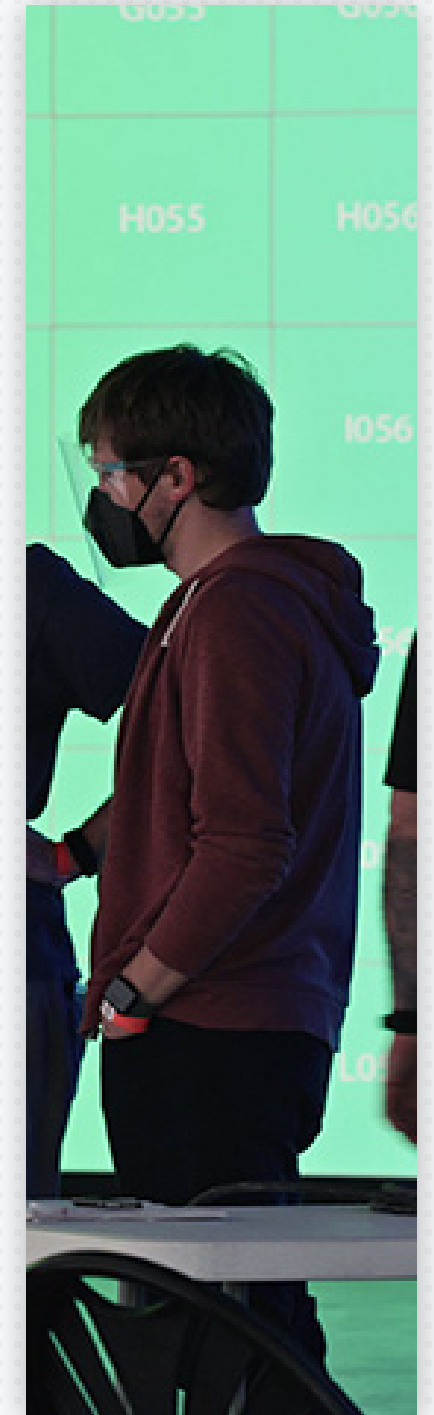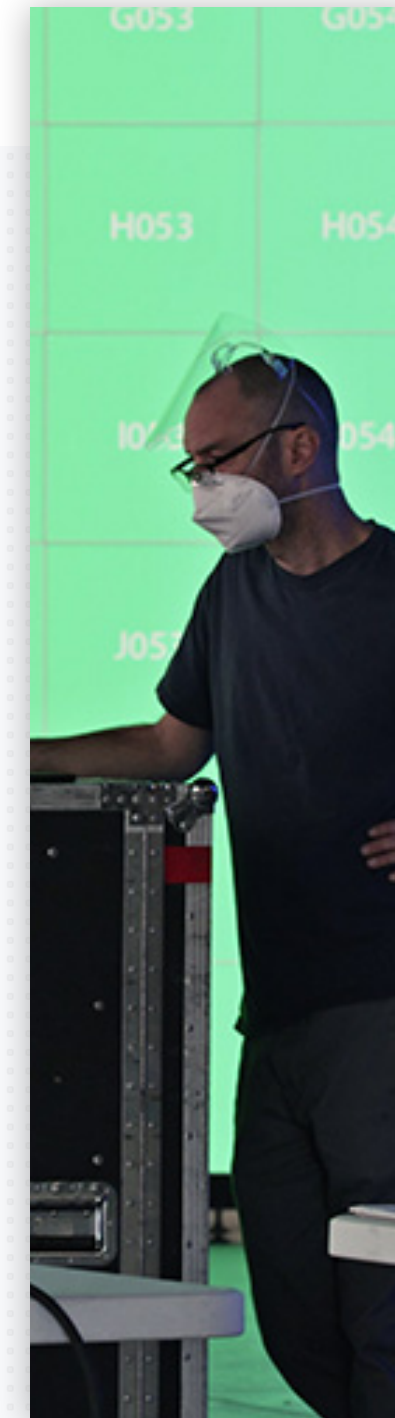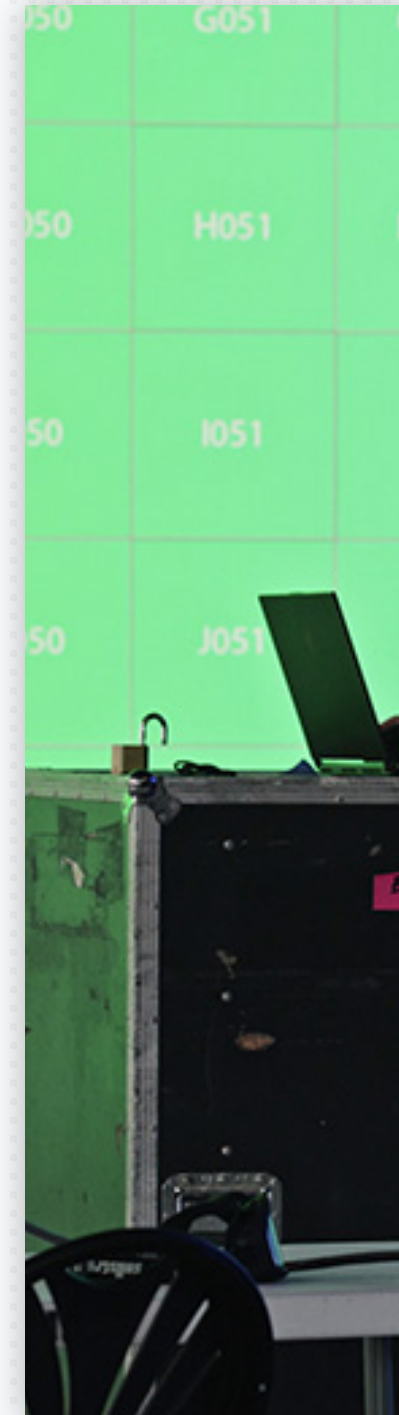
This new *Virtual Production Workflow* becomes a new approach to filmmaking which could transcend any incremental changes in underlying virtual production technologies or tools

The truth, as always, is somewhere in the middle. VP was maturing, from the early days with MoCap and Simulcam, to a modern suite of similar technologies all exploiting the emergence of real-time ray-tracing in game engines. The stage was set, and Virtual Production technologies were nearly ready for their prime time close-up when a global pandemic shined the spotlight on them. But, as with any workflow innovation, they require new tools, new skills, and new personnel, which generate new problems and new solutions. In this paper, we make an open and honest assessment of where Virtual Production is today, discuss its benefits and downsides, and provide practical advice and tools for production teams interested in trying VP technologies on some, or all, of their next show.

We make the case that individual VP technologies in isolation are an interesting evolution of the production process, but it's when they are combined that they offer a potential revolution. It is only if these new technologies are systematically applied in a new workflow process that we can take full advantage of them. We dub this new process "the Virtual Production Workflow" and demonstrate how, if applied correctly, it can enable more iterative decision making that is flexible and fast and lower the enormous stress of creating modern episodic TV and movies.

But these advantages require a new rigor in production planning as well as changes to budgeting and scheduling of both tasks and entire departments. This new Virtual Production Workflow becomes a new approach to filmmaking, which could transcend any incremental changes in underlying virtual production technologies or tools.

The change to a real-time Virtual Production Workflow will likely be the longest lasting impact from today's Virtual Production technologies, creating ongoing ripples through our industry for

decades to come. Time is also of the essence – we are in an environment where the time and budget constraints on production have never been tighter and may continue to get worse. We simply cannot keep executing the way we have done in the past and expect our legacy workflows to cope with the sheer volume of high-quality content that needs to be created. In this paper, we demonstrate that a VP powered workflow may be our best chance to make the sort of dramatic improvements to production efficiency that we'll need to cope with ever increasing studio demands.

Credits

The paper was written with the sponsorship and kind contributions of the Virtual Production experts at NEP Virtual Studios as well as other creators, producers, and studio executives who were willing to share what they have learned from years of hands-on experience with Virtual Production technologies. At times of massive innovation, we have always learned from those industry leaders that have experimented, stumbled, fell, picked themselves up, and been willing to share to help others and to keep the innovation ball moving down the field. To those industry leaders in Virtual Production and real-time workflows, we are forever grateful for your contributions to this paper and the process of sharing.

A full list of acknowledgements is in **section 7**.

We simply cannot keep executing the way we have done in the past and expect our legacy workflows to cope with the sheer volume of high-quality content that needs to be created

*Virtual Production**

uses technology to join the digital world with the physical world in real-time. It enables filmmakers to interact with the digital process in the same ways they interact with live-action production.

*Virtual Production** definition from the VP Glossary

2 - Demystifying Virtual Production

2.1 Defining Virtual Production[2]

Virtual Production covers not a singular technology but a combination of integrated systems, and there's really nothing virtual about it. So, it's not a great descriptive name but it's what the industry has settled on. "Virtual Production" is not virtual but real, physical production, on a set, with cameras, microphones, actors, and props all combined with real-time visualization workflows. The key distinction with legacy production is that VP is enabled by a suite of new and emerging technologies which combine physical and digital elements on-set, in real-time, to enable real-time feedback and iterations. Some examples of virtual production technologies include **world capture** (location/set scanning and digitization),

visualization (**PreVis**, **TechVis**, **PostVis**), performance capture (**mocap**, **volumetric capture**), **simulcam** (on-set visualization), and **in-camera visual effects** (ICVFX). Our focus in this paper is specifically narrative content (i.e., excluding live news and sports) and Virtual Productions using camera tracking, real-time 3D environments rendered on LED walls to create immersive environments with the illusion of depth and perspective for cameras shooting action in front of the LED walls. There are many great technical resources and training on the complexities of these components[3], but since this is not a technical resource, we are deliberately leaving those discussions out to instead focus on the budget, workflow, and strategy of Virtual Production.

[2] There are certain Virtual Production terms of art used in this document. Rather than create a lengthy glossary, we have instead linked these terms to the definitions agreed upon by the peer-reviewed Virtual Production Glossary – jointly created by the Visual Effects Society and the American Society of Cinematographers with contributions from Epic Games and Netflix. The first time a new term is used or defined it is **bolded**, so it is apparent which terms are linked to the VP Glossary.

[3] There are some great resources in Section 8 for those that want to learn more on the technology.

In many ways, Virtual Production technologies and workflows are more akin to the 'Special FX' of classic filmmaking – where what was captured by the camera was "in the can" and sent to the editor. As digital Visual FX emerged as a massively powerful tool in the filmmaker's toolbox, it necessitated a "fix it in post" mentality as the shots captured on-set were going to be subject to massive changes and iterations occurring months later via digital artists. Today's cast and crews have learned over the years how to adapt what, and how, they shoot to try and predict what may happen in post produced VFX, but it's an imprecise art, and the final content may vary wildly from what the production team imagined when they were on-set. Virtual Production technologies allow for many of those creative decisions from VFX/post to occur back on the set, or even before, when the full creative team is together and team members can iterate in real-time to capture and agree on something much closer to final rendered content. Virtual Production can therefore offer the best of both worlds – the creative power of VFX with the on-set efficiency of Special FX. But these technologies cannot be immediately harnessed like other new equipment – a new lighting rig or a camera dolly – can be; instead, VP requires advanced planning, new facilities, and significant changes to the workflow.

Virtual Production can therefore offer the best of both worlds – the creative power of VFX with the on-set efficiency of Special FX.
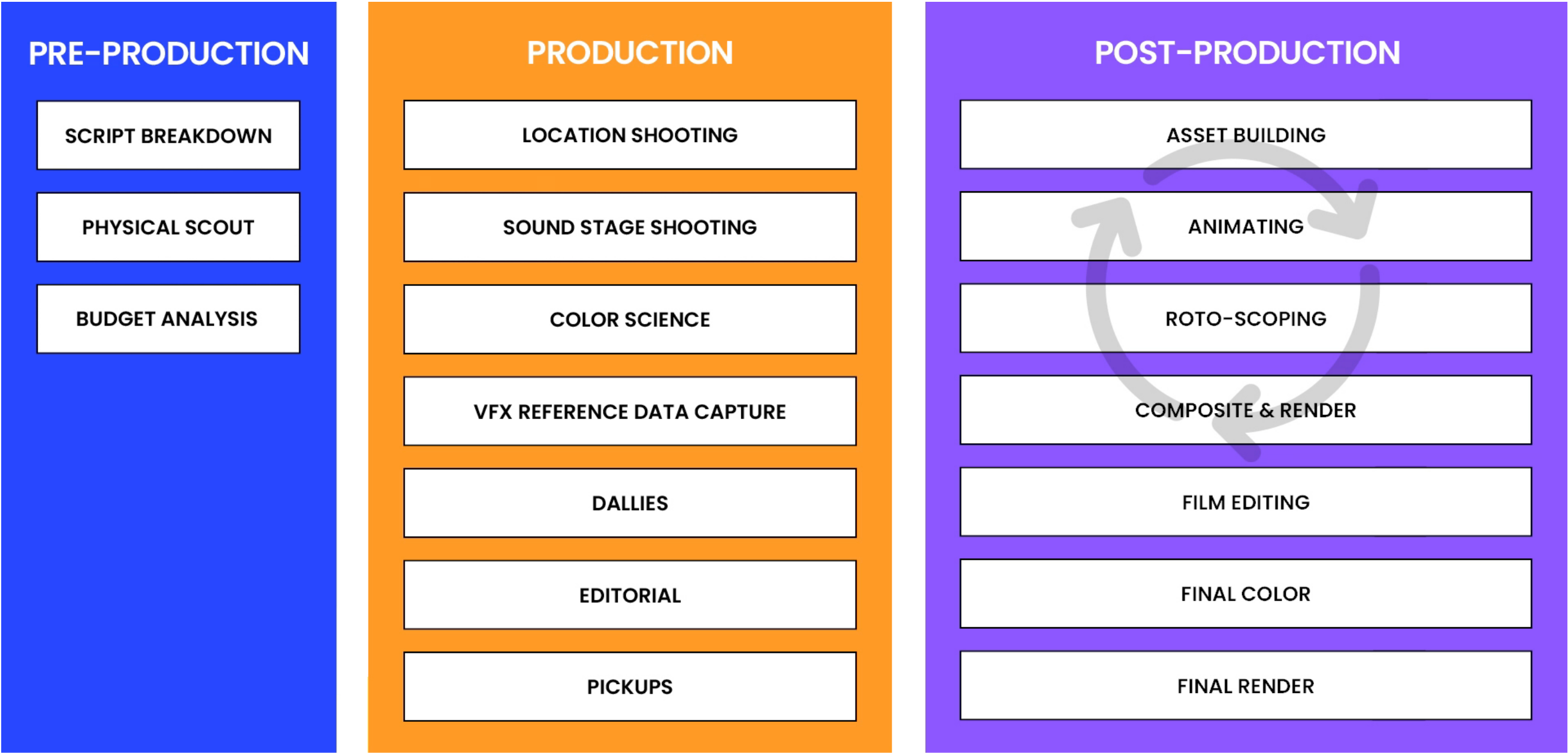
2.2 *Virtual* vs *Traditional* Production Workflows

Production technologies have been evolving since they were invented in 1889, so there is really no such thing as "traditional production." However, for the sake of this conversation, we'll define "Traditional" as the tools, techniques, roles, and workflows that have become commonplace in modern filmmaking from the early 2000s onwards, including using a green screen, rotoscoping, offline compositing, and non-real time rendering – typically using CPU powered render farms at VFX facilities to produce the final images.

There are many steps in the creation of asset packages for offline VFX, including VFX asset pushes from editorial to the VFX vendor, rotoscoping to isolate elements in the scene, rendering and compositing the new 3D elements into the plates, and then returning the shots to editorial for review.

PRE-PRODUCTION	PRODUCTION	POST-PRODUCTION
SCRIPT BREAKDOWN	LOCATION SHOOTING	ASSET BUILDING
PHYSICAL SCOUT	SOUND STAGE SHOOTING	ANIMATING
BUDGET ANALYSIS	COLOR SCIENCE	ROTO-SCOPING
	VFX REFERENCE DATA CAPTURE	COMPOSITE & RENDER
	DALLIES	FILM EDITING
	EDITORIAL	FINAL COLOR
	PICKUPS	FINAL RENDER

Traditional content creation functions broken down by where they appear in the process.

Figure 1 - Major production processes that move with Virtual Production
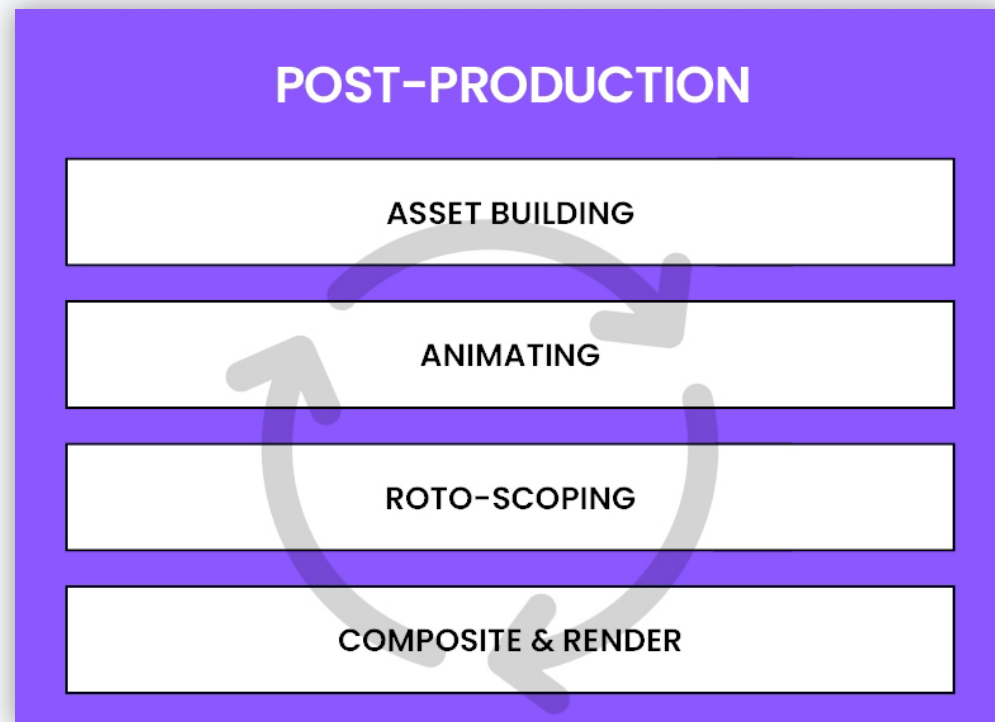
Figure 2 - Iteration occurs in Post VFX in the traditional workflow

The cyclical shape highlights where many major creative decisions are made, with the digital and physical elements of the workflow coming together in offline VFX. These typically occur in the post-production world, with cycles of edits, proxies, plate pulls, animation, compositing, rendering, and review/ approvals. As physical production has largely wrapped (or moved on to some pickup shots), this innovation is happening with the director and VFX supervisors but not always with the benefit of the entire crew of production talent and art department.

Budget and time are the two largest constraints on production, and these lengthy post-production cycles of data movement, sharing, waiting, changing, and trying again, so late in the filmmaking process, cause stress and often a "it will have to do" mentality as time or the budget ticks away. The true benefit of Virtual Production is to move these iteration cycles forward dramatically, with the digital effects occurring and being composited in the same time and place as the physical elements. This can enable many more iteration cycles, but, crucially, it also shortens the time between iterations, dramatically reducing time wasted on data transfers, confusion on which file is the latest version, badly named files, time zone mismatches, and other problems with offline VFX during post-production.

Virtual Production is not a single technology, but more a collection of integrated tools and technologies that have matured to create this opportunity to dramatically improve the on-set production processes. As the diagram animates, you can see what changes in our generic production flow when we introduce Virtual Production Technologies.

The true benefit of *Virtual Production* is to move these iteration cycles forward dramatically, with the digital effects occurring and being composited in the same time and place as the physical elements

As can be seen by the animation, some of the workflow tasks historically in post-production VFX, including asset building and environment creation (digital set building/design), need to be moved significantly earlier in the development cycle, so they can be used during onset principal photography. This reduces the risk of time and budget crunches at the end of production, but also necessitates adjusting budgets (**see section 3**) and schedules to accommodate these changes. Overall, you can see the time allocated to pre-production and planning is now much larger, but is compensated for by a shorter physical production window and a much shorter post-production window as much of the repetitious tasks have been removed (including time consuming push/pulls, rotoscoping, offline renders and compositing).
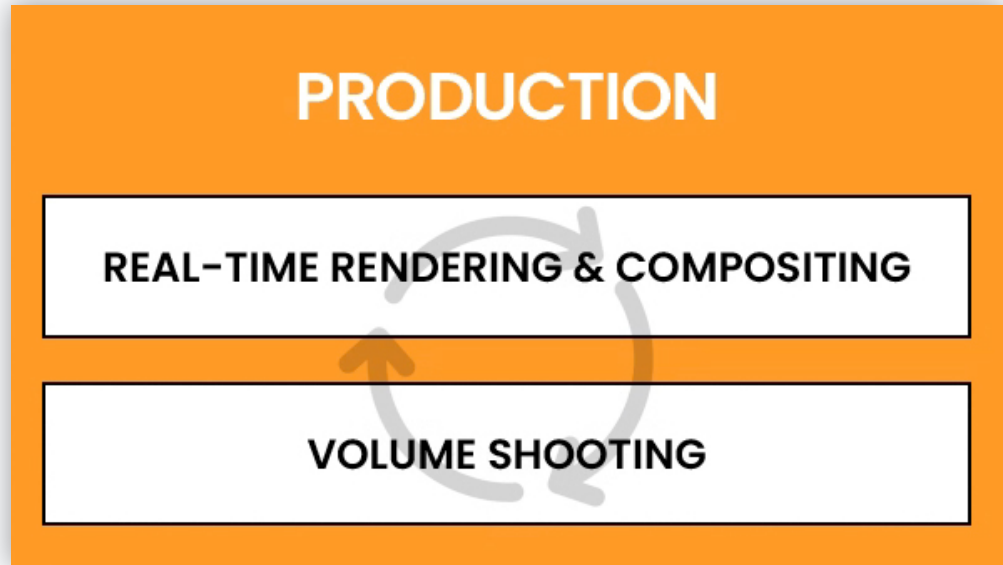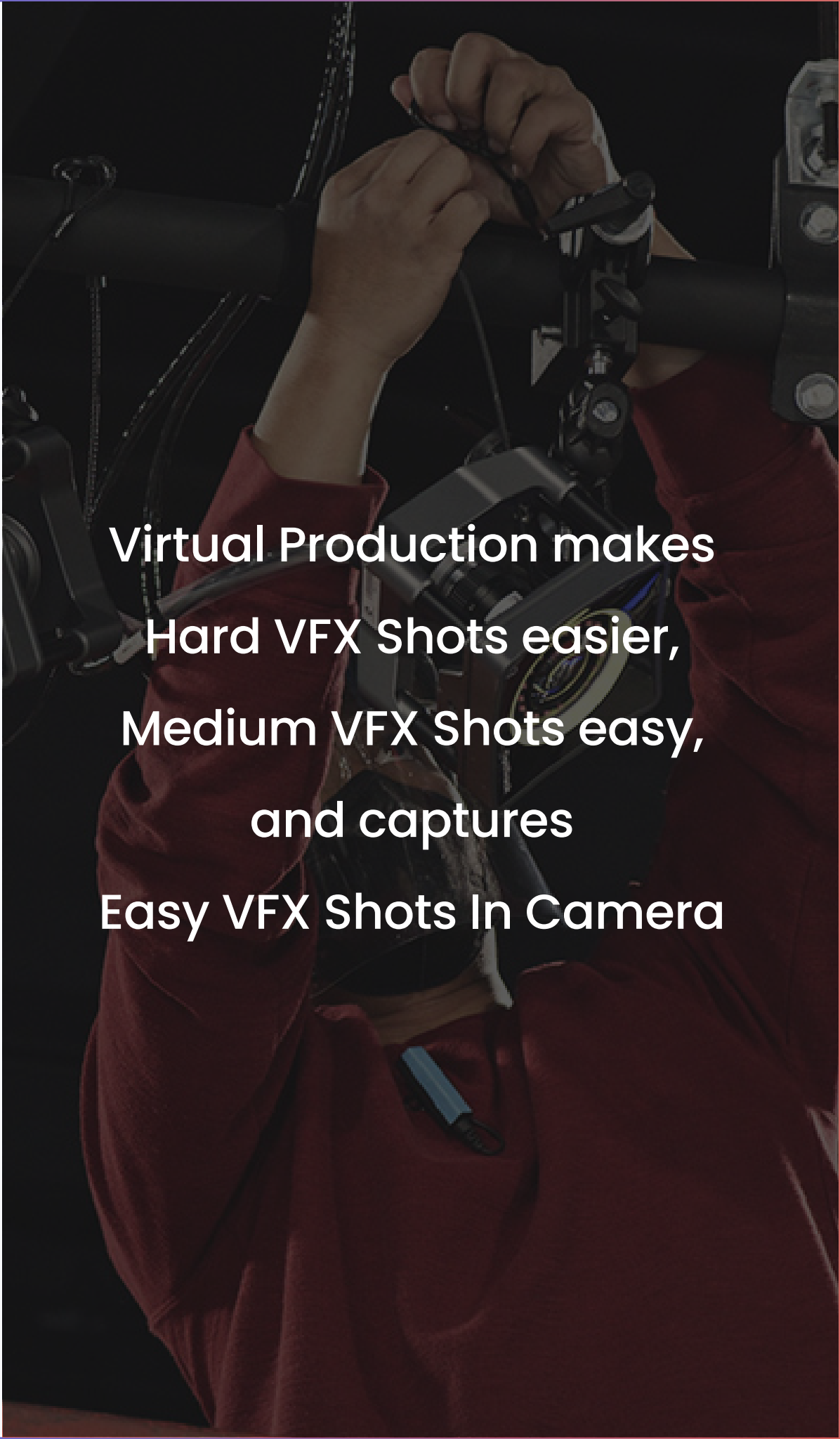
That is not to say that with Virtual Production there's no need for any post-produced VFX at all. We have left room for green screen shots and some VFX in the post-production window because Virtual Production today can't be used for every shot, and in some cases, VFX shots captured in camera (In-Camera VFX) will not be considered 'final' and may need post-production VFX cleanup work.

Note that a major iteration cycle also moved forward (although of course there is still iteration in post), and it now unlocks major creative decisions about digital elements that can be made in pre-production and with iteration on-set where the physical and digital world can now be seen together. It is this continuous iteration cycle that opens up the opportunity for new efficiencies throughout the production – and allows the filmmaker to see what they have and what their show will be like much earlier in the process. This approach requires new skills and a totally new approach to planning in the early phases of a project – see **section 5** for recommendations on how to prepare for these changes.

PRODUCTION

REAL-TIME RENDERING & COMPOSITING

VOLUME SHOOTING

Figure 3 - Iteration cycle that has moved to pre-production phase

Virtual Production makes
Hard VFX Shots easier,
Medium VFX Shots easy,
and captures
Easy VFX Shots In Camera

2.3 Virtual Production Enabled Workflows

While a show could easily use a pop-up LED wall as a virtual background for a single scene (for example, a dialog scene on a train with the outside view provided by the LED screen) and dub the production a "virtual" one, it is unlikely to see the sorts of transformational change and benefits we're discussing in this paper. **Any of these VP technologies, when used *individually*, can incrementally improve a production workflow, but it is the wholesale adoption of many of these technologies together that enables the groundswell of change that unlocks a true next-generation workflow and its associated benefits.**

We're defining this way of working as a "Virtual Production Workflow" as it is enabled by Virtual Production technologies but really encompasses a change in the production approach rather than any specific change in technology. In this paper, there is an intentional and clear separation between Virtual Production Technologies, which are enablers of this more profound change, and a Virtual Production Workflow. A robust Virtual Production Workflow process will support, adapt, and scale to continuous changes in underlying Virtual Production Technologies. Adopting this more holistic process now not only future-proofs a producer and production team from changes during their current project but also builds the skills for the future disruptions that are coming as real-time collaborative pipelines will continue to transplant slower offline rendering and iteration processes. Investing time to explore Virtual Production technologies and the workflows they enable now will ultimately pay dividends for years and decades to come.

A robust *Virtual Production Workflow* process will support, adapt and scale to continuous changes in underlying *Virtual Production Technologies*

2.4 Visualizations

The process of Pre-visualization, or PreVis, has been widely accepted and is broadly used for sequences with complex action and often with a lot of VFX. Our scope of visualizations, however, includes other steps that can and should be used to enable this new VP Workflow. The number of "vis" has expanded in recent years to include "Pitch-Vis," "Tech-Vis," "Post-Vis," and others, but they all speak to the need to effectively plan, in 3-dimensions, to minimize negative impacts, and to streamline the most expensive parts of production (physical and post-production).

Whereas PreVis has been used for complex shots or certain types of action content (typically blockbuster movies and TV shows), we now see it being more broadly accepted in all manner of content because of its proven ability to save time and money elsewhere in production. The blocking out of cameras and lighting, laying out of complex set pieces, and the lowering of barriers of entry to PreVis (with more broadly available PreVis artists) now allow us to make PreVis a foundational element in the new Virtual Production Workflow.

In the Virtual Production Workflow diagram, we included some recommended Visualization steps that are integrated into the process to unlock the potential of Virtual Production technologies. They include the following:

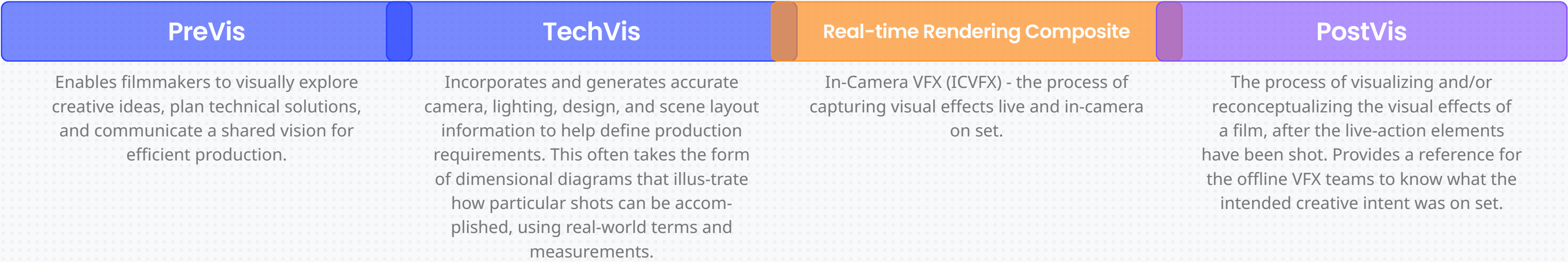| PreVis	TechVis	Real-time Rendering Composite	PostVis
Enables filmmakers to visually explore creative ideas, plan technical solutions, and communicate a shared vision for efficient production.	Incorporates and generates accurate camera, lighting, design, and scene layout information to help define production requirements. This often takes the form of dimensional diagrams that illus-trate how particular shots can be accom-plished, using real-world terms and measurements.	In-Camera VFX (ICVFX) - the process of capturing visual effects live and in-camera on set.	The process of visualizing and/or reconceptualizing the visual effects of a film, after the live-action elements have been shot. Provides a reference for the offline VFX teams to know what the intended creative intent was on set.

Figure 4 - Blended iteration cycle for visualization

This digital iteration cycle for visualizations is shown intentionally blended, as each transition adds extra fidelity of detail and texture to the shot until final pixels are achieved. The process becomes similar to the iteration cycle of animated shows, where the iterations go through the script, to the storyboard, to scratch animation, and ultimately to final renders.

Each step adds a successive quality to the visuals:

Storyboard	Layout	Animation	Final Revisions & Render

Figure 5 - Blended iteration cycle for animated content

In the VP Workflow, the PreVis work is not just for action scenes or those that may end up shot in a VP volume but is also for layout and to prepare for all shooting locations and scenes. The extra time spent on PreVis and TechVis is a large reason why the pre-production phase is shown as longer in the VP Workflow; however, the time saved in these planning phases can unlock more time and budget savings later in the process, when costs and stresses are much higher.

2.5 The Roles and Responsibilities of the Virtual Art Department (VAD)

One of the biggest changes for producers to plan for is the creation of a *__Virtual Art Department__*, or *VAD*. The VAD includes digital worldbuilding, creating the required CG assets, and validating and adjusting them so they will work on the selected 3D volume(s). The VAD may also absorb some existing production functions such as PreVis, On-Set VR/AR, and MoCap. In some cases, the VAD could be merged with Concept and Production Design to form an expanded Art Department. By establishing a single Virtual Art Department instead of fragmenting those functions across multiple departments, the production benefits by centralizing those with similar skill sets – artists and technologists that are expert in CG assets and the real-time rendering of them. While much of the digital artistry in VAD overlaps with skillsets found in VFX vendors, a VAD artist will know how to optimize those assets and environment for on-set capture – which may require modified assets or depth of layers found in traditional offline VFX renders. A 3D volume using LED walls is typically out of focus to the camera because the narrow depth of field is focused on the key characters – and a skilled VAD can take advantage of that, much like any other movie magic "sleight of hand." The VAD works closely with the cinematographer and any offline VFX teams to ensure that what is captured on-set is correctly lit and exposed and will complement the post-produced VFX shots.

The move to digital assets and construction can also limit the work on physical construction of sets and set dressing. These digital assets also have major benefits over their physical counterparts – they never deteriorate, scratch, or scuff; can be easily switched out or redressed; and are very cheap to store. These saving are especially important for multi-season TV shows that need to break and store their sets ("fold and hold"), or share stages where sets need to be rolled in and out and for franchise movies that often revisit the same locations. It's hard to directly translate the costs of physical set construction versus digital set construction as they're dramatically different art forms. We may see the rise of digital set marketplaces that will rent entire 3D environments that can be minimally dressed and available anywhere in the world, providing much more flexibility to producers and studios.

There is no firm consensus on when in a production the VAD should start up – ideally it would be soon after production design starts, to help create digital assets for environments. In some cases, this may be after PreVis starts, and sometimes PreVis will be earlier than production design – in which case it would be helpful to select a PreVis team who has some understanding of VAD workflows in case they can leverage the PreVis assets as first-pass VAD assets.

A VAD isn't a panacea – like any tool, it's only as good as the team that wields it. If a production is not well planned, without a clear PreVis or production plan, the VAD will be constantly trying to catch up and may delay production instead of accelerating it, especially if they need to source or even create new digital assets that were not expected for a particular shot.
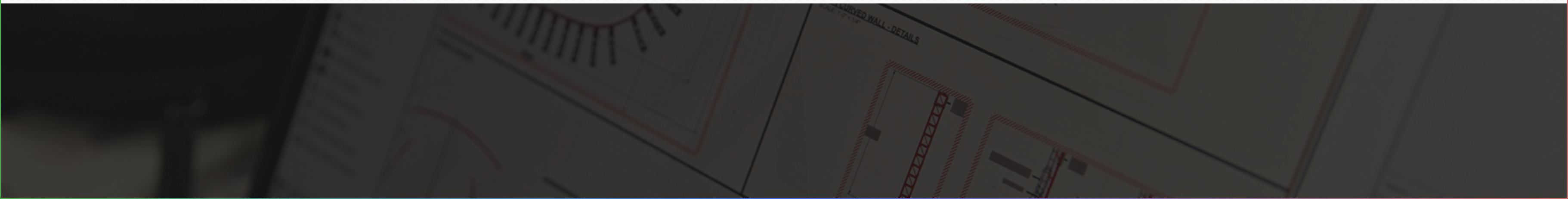
2.6 Virtual Production Stage Operations

The selection of a team to run the VP stage is critical as experience is vital and there are limited people in the industry with such expertise. The team will be responsible for running the on-set equipment required to run the real-time engine of the 3D volume (aka the **Brain Bar** or **Volume Operations**). Some rental volumes will be supplied with the team to run the volume and help productions map their productions and 3D assets correctly to the specific space and rendering capabilities. Some VAD teams can also run the production volume, but only if they have the right mix of expertise. Much like any other department on a production, the VAD is best made up of team members with a range of skills (only some of which need to be physically on set) – in this case, digital artists, real-time software engineers, computer hardware engineers, and experts in the LED, projection, or other display technologies.

A well-practiced VAD and Volume Operations team will have a scene ready for a director before the main unit is ready to shoot, can make real-time adjustments to that scene/environment as requested, adjust to any problems (**see section 5**), and quickly set or reset a scene – all of which can contribute to the time savings for virtual production shoots versus traditional shooting.

Virtual Production Roles

VP Supervisor

VAD Artists
- Asset creators
- Previs artists
- Layout artists
- Lighting artists

Volume
- Tracking team
- Camera team
- Volume Control tech artists
- Virtual Scouts - camera and scene blocking

Setup
- Wall configurators, setup tech artists / NDisplay Artist

Colorist

Volume Control/Brainbar
- UE Tech Artists / Operators
- Pipeline Engineers
- Tools dev, Controls Dev

Heads of Production

Director

Executive Producer

Line Producer

Director of Physical Production

Physical Production Producer

Physical Production Team

Camera Team

A gaffer key grip and a dimmer board op

A first AC

Lighting/grip vendor

Camera Operator

Crane / Dolly / Dana Dolly + Operator

Tracking Specialists

Coordinators

VFX Supervisor

VFX artists
- Previz character artists
- Pipeline engineers

Real world data capture
- Lidar or drone scanners
- GIS data wrangler

Anim supervisor
- Character tech artists
- Animators

Post Vis Comp Artist

Post Layout artists

Coordinators

Art Department

Art dept prop and set builders

On set in volume Art Dept integration

VAD Liaison

Coordinators

VAD Team

Asset Creators

Layout

Lighting and Shading Artists

Character Artists

Producers

Coordinators

Figure 6 - Job titles in Virtual Production (Courtesy BecomeCGPro.com)

2.7 Staffing Virtual Production

In the last 20 years, the work of out-sourced VFX Vendors has exploded as the number of shows with some element of digital 3D has increased beyond animation and sci-fI shows to include period dramas, romantic comedies, and even documentaries. Offline VFX was, of course, a post-production exercise driven by the VFX supervisor on the production, usually liaising and coordinating with supervisors at one or more selected VFX vendors. Those vendors typically included asset building, digital scenery, animation, rendering, and compositing and managed all the review/approval/edit changes as the production approached its delivery deadlines. Virtual Production, and especially the rise of the Virtual Art Department, redefines where many of these traditionally post services occur and, therefore, the role of the VFX vendors themselves.

Major VFX vendors, of course, have recognized this change, and many are investing in building dedicated VP teams to push their services earlier in production, which has the added advantage for them of a closer relationship with filmmakers as they can start much earlier in the production and a potentially lower chances of multi-vendor VFX bids later in production. But, as we have discussed, the skillset of on-set, real-time digital artists is similar but not the same as that of their offline VFX counterparts. Likewise, the complexity of offline VFX elements, sometimes with many layers and simulations, is not well suited to today's real-time game engine renders onset. The quality of digital assets for PreVis, TechVis and PostVis is very different from that of final pixel renders in offline VFX. As VFX vendors explore where their new expertise should land in a VP enabled world, producers should ensure they build teams and vendor relationships that match the correct level of expertise and digital imagery required for each step in production, which may or may not include the traditional VFX vendors.

2.8 The Changing Scope of VFX Vendors

As with any new technology evolution, there is currently a shortage of skilled experts who have cut their teeth on Virtual Production and are available for new productions. When staffing and budgeting the following may be useful in ensuring the production is sourcing the right talent and job titles. Some of these roles are currently provided by VP facility vendors or VFX vendors, some are on contract to the production and some studios are providing the expertise directly.

2.9 Future Proofing Filmmaking

At the time of publication, the VP technologies we've discussed are considered new and disruptive, but they will also continue to change and evolve. LED volumes will get higher resolution and newer display technologies, mocap will move marker-less, new depth sensing technologies will emerge, on-set rendering will improve with better quality and faster frame rates which may allow "ghost frames" for multiple cameras to shoot ICVFX simultaneously, live digital characters may appear onstage driven by real-time mocap digital puppetry, and more captured pixels may become final pixels. We can also expect to see an explosion in creative tools powered by Artificial Intelligence (AI) and Machine Learning (ML) that instead of replacing creatives will be able to automate mundane processes and understand nuanced direction given in natural language to create or modify complex asset packages.

These technical innovations, and no doubt many more, will come over the next few years, and while they will be disruptive to traditional workflows, if a new and dynamic VP Workflow is adopted now, these disruptions will be minimized as this new approach to filmmaking is flexible, based on software defined workflows[5], and able to accommodate such changes. And that is the true opportunity for producers to grasp – a future workflow where the team can embrace change instead of shudder when it is mentioned.

In many ways Virtual Production is a harbinger of bigger changes coming to the media creation and distribution ecosystem. If we look at a timeline of the technology innovations behind Virtual Production techniques, we can see a consistent and constant drumbeat of improvements – proving that the VP is far from emerging or experimental as it is often misconceived to be.

In fact, it's fair to say that **while Virtual Production has not reached the commodity stage, we are certainly beyond experimentation and into stable and scalable deployment**. The tools and technologies behind Virtual Production are now proven and repeatable. While we're not focused on live events and live TV production, many of the core VP technologies, including game engines, AR, real-time compositing, and In-Camera VFX, have been used for years in news and sports production that have much higher fault tolerances than narrative TV and movies because they are live-to-air.

[5] For more on the benefits of Software Defined Workflows, check out this MovieLabs video: Software Defined Workflows explained - MovieLabs
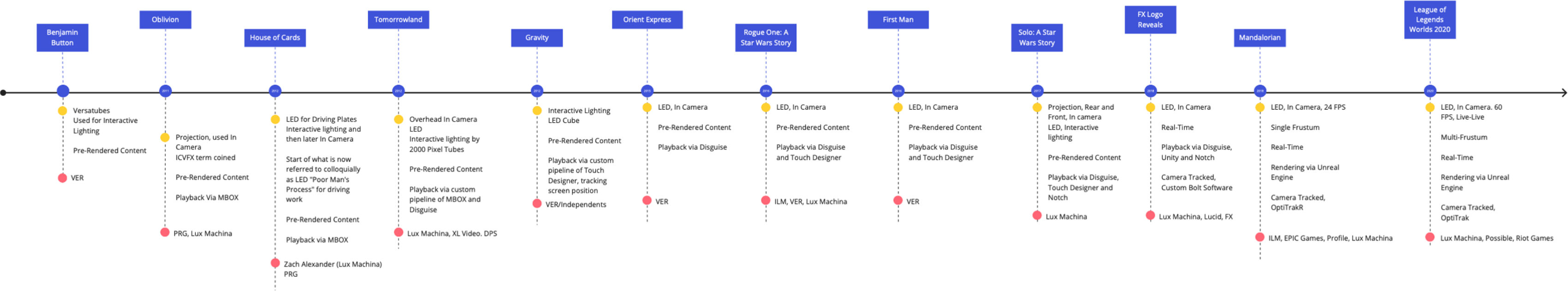
Figure 7 - Demonstrates how virtual production technologies have iterated since 2008 (Courtesy: Phil Galler)

In 2019, MovieLabs published a Whitepaper "The Evolution of Media Creation," often called "the 2030 Vision," which foretold how many emerging technologies (including the cloud, software defined workflows, and real-time rendering) will change filmmaking. Indeed, there has been a broader change in entertainment in which gaming and film making tools are fusing, which will enable an entirely new hybrid narrative media where the audience has agency.

During the 2000s, our industry built up major barriers to entry through high CapEx required to participate in digital VFX (render farms costing millions of dollars per site) and creating 3D models with large talent pools in creative cities (like high OpEx). But now the major cloud operators with enormous investment potential (Amazon, Microsoft, Google) can augment the role of post-production and VFX vendors and are more than willing to fund equipment and amortize it for use on individual productions through high margin rentals. Now small VFX companies or even individuals can rent enormous render farms for a few hours with no CapEx required, opening up competition. The pandemic also forced the industry to allow a "work-from-anywhere" model, opening a global talent pool and freeing digital artists to be able to work from anywhere. Although we have lost many talented VFX artists to the more lucrative and predictable games industry, we now have the ability with the remote tools and workstations to source talent from anywhere in the world.

Virtual Production has the potential to cut across our silos of production and actually unify teams, tools, and technology:

Breaking Down Production Silos
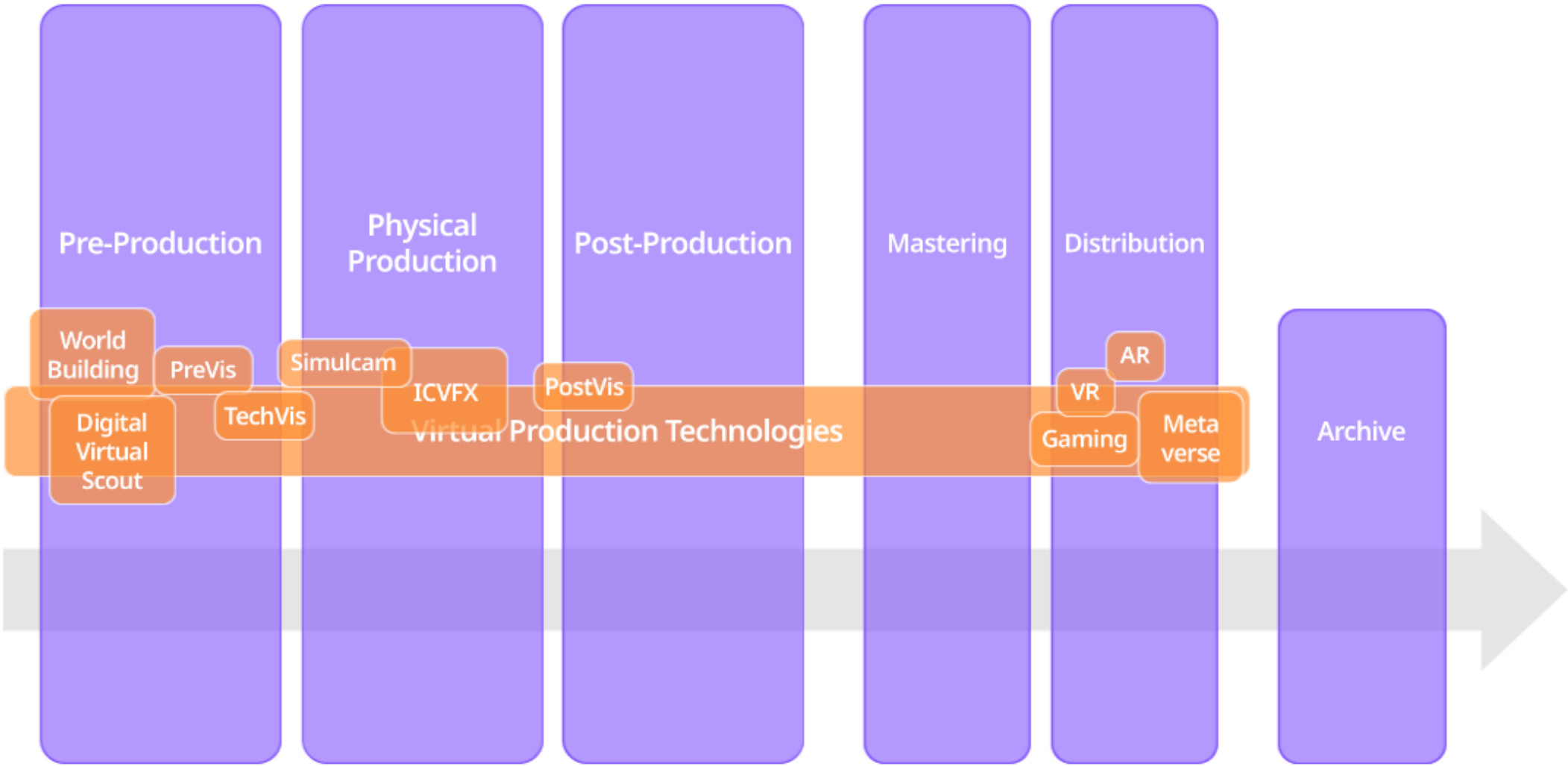
Figure 8 - Virtual Production is the first technology that spans across the stages of production, breaking down silos between teams, workflows, and tools.

The suite of Virtual Production technologies may be the first time that we've introduced a technology in filmmaking that can be funded and invested in by adjacent industries and with which Media & Entertainment can benefit. While the real-time rendering needed for Virtual Production was developed for video game engines, which also spawned AR and VR, the LED volumes we're using were first developed for live events and concerts, and the ability to merge physical and digital realities is being used in architecture, design, and a host of other industries and ultimately has led to the much abused term 'the metaverse.'

For media creation, we don't need a public metaverse but a "creatorverse," where all the virtual production technologies combine to allow a truly seamless digital/physical environment and where creators can explore a rich canvas of reality and imagination fusing together in real-time. With other industries buying and funding the same tools, we get the benefit of their investment at potentially lower cost, but we also need loud enough voices in those product conversations to ensure that our needs are heard and developed into these future "creatorverse" tools.

For media creation, we don't need a public metaverse but a "creatorverse," where all the virtual production technologies combine to allow a truly seamless digital/physical environment and where creators can explore a rich canvas of reality and imagination fusing together in real-time

3 - Budgeting for Virtual Productions

3.1 - Measuring Time and Cost Implications

We have established many of the differences between Traditional and Virtual Production, some of which have tangible impacts on production schedules and budgets. In this section, we'll discuss in more detail how to measure those changes, address if they are reductions or increases in line items, and explore how to optimize the use of VP technologies to ensure more of the budget translates to what the audience sees on screen. This section was written with the input of teams with years of experience in traditional and virtual production techniques and is based on real projects and budgets.

We are focused here specifically on the movement of some or all shots from traditional stages to the use of Virtual Production Volumes, an LED wall to shoot against and the goal of capturing more of the final pixels through the camera than traditional green screen offline VFX. We've assumed a Virtual Production stage rental in a single location like **Tilleth's Prysm Stage** (as opposed to buying or building a VP volume – **see section 5.4** for the implications of each) and shots using 3D assets and tracking (see **section 5.1.2** for details on 2D, 2.5D and 3D shots).

There are many ways to measure the impact of changes in production technology and workflows. We have studied the cost savings from reduced travel to remote shooting locations, the movement of VFX asset building from post-production to pre-production, and the reduction in time spent on set (even a day or two can offer considerable savings through a more focused shoot schedule). While no two productions are the same, there are sufficient commonalities that we can provide some ground rules and extrapolate what may happen across different production budgets and schedules. For that, we need a common model that we can use for illustration and to discuss the impacts of Virtual Production Workflows.

3.2 – Introducing the Sample Budget/Schedule

This sample budget is for a reference project (in this case a $100 million movie) with some basic assumptions made for a VFX budget, shoot schedule, and departmental breakdown. It allows us to explore what happens to a hypothetical overall budget, specific department spends, and schedules when a project moves to a Virtual Production Workflow.

While we picked a single title to make the example easier, the spreadsheet can be easily modified to model an episodic TV series or even a franchise of titles, where economies of scale in asset building can generate considerable cost savings.

On the spreadsheet tab 'Traditional Production,' there are a number of cells with blue borders – these are the key inputs required to model a production spend and schedule. You can change them to whatever you want. The spreadsheet automatically phases the spend across the weeks of the production and calculates the total production phases and overall schedule length, among other things.

The pro forma of the spreadsheet includes some initial assumptions about the impact of moving to a Virtual Production Workflow, which are shown in blue boxes on the 'Virtual Production' tab. We are assuming here that the production is not doing an occasional tweak with some scenes moving from green screen to LED volume but instead adopting enough components of the VP Workflow to elicit major changes and benefits as discussed in Section 1. These initial assumptions were developed by the experts at NEP Virtual Studios in conjunction with creatives who have delivered multiple VP shows. Even though they're based on actual productions, we recognize that they are simply assumptions and therefore spreadsheet users can modify these assumptions to model different scenarios specific to their production.

With these initial assumptions, we can examine some of the implications of a move to a VP Workflow on this nominal title. Of course, these are only examples for a fictious production, but there are some important learnings we can deduce...

Download for Free

Accompanying this paper we're introducing a sample budget/schedule spreadsheet for readers to explore, edit and duplicate.

SAMPLE PRODUCTION	INITIAL ASSUMPTIONS
Total Budget	$100M (changes to $89M with pre-defined VP assumptions)
VFX Budget	$30M (changes to $12M with VP)
Pre-Production/Planning Phase	10 weeks Increased by 40% for Virtual Production
A Shoot Schedule of	12 weeks Decreased by 10% for Virtual Production
A Post Schedule of	30 weeks Decreased by 30% for Virtual Production

Table 1 - Initial assumptions in the spreadsheet when moving from traditional to virtual production, all of the assumptions can be modified to try different scenarios.

3.3 – Budget Changes with Virtual Production Filmmaking

The **Virtual Production** tab on the Sample Budget automatically adjusts the budget, timing, and departmental spend breakdown to accommodate for the changes to a VP Workflow.

The Sample Budget also contains a basic week-by-week spend schedule. While not designed to replace a production management tool, it is designed to simply show where the departmental costs move to and from. For example, many of the production changes with a VP Workflow impact the 3D assets usually created by VFX vendors in post-production. With VP workflows, those assets are needed much earlier in production, so the spreadsheet shows how these big changes in scheduling impact the spend and the time required for pre-production and planning phases.

3.3.1 – New costs with Virtual Production

Let's look at the impact on the budget with new costs for Virtual Production and departments where the spend will increase.

Virtual Art Department Costs

As discussed in **section 2.5**, the Virtual Art Department comprises many skills and people from different disciplines and can extend the period of pre-production as it prepares all the assets to be used in VP volumes. Even though the VAD is a new department, our model shows it borrowing from the expertise and spend of other traditional departments. In our sample budget, we have allocated 50% of the VFX spend and the Special FX budget to the VAD and reduced the set costs (design, construction, dressing and striking) as some of their work will now be digital. The VAD, therefore, is an example of reallocated spend rather than new spend, and by refocusing and reprioritizing the production schedule and budget, the benefits of the VAD can enable faster production at lower overall costs.

The Virtual Production Stage

The use of a capture volume instead of a traditional empty stage obviously changes the budget dramatically and drives many of the changes in crew required to support the additional technology. In our reference budget, we have assumed a VP stage rental versus a traditional empty stage rental which increases rental costs by 4-10x, depending on scale and complexity. For a permanent volume, these increased costs include the cost of the technical talent to operate the stage and equipment, processing and controls, plate, and real time playout; however, they do not oversee the creative assets, which are covered in the VAD. Additional costs may include stunt rigging and reconfigurations of the volume.

Obviously, VP stages come in all shapes and sizes, ranging from a small 'roll in' monitor to use as an exterior of an interior shot, to huge, curved LED walls and multiple LED ceiling panels to create an enveloping VP environment. We're modelling the more high-end scenario to highlight budget differences, but really uses of VP stages will be as varied as traditional stages in terms of size, features, location, and functionality. The questions for the production team will include which is the most appropriate stage (or stages) for the shot list they have to accommodate; how to load the stage(s) for optimum cycles of build, shoot, and break; and how to handle the 2nd Unit, if applicable.

3.3.2 – Cost Savings with Virtual Production

Now that we've looked at the extra costs from Virtual Production, let's consider the areas where budget savings can be made and how they are applied in the reference budget.

Travel

Obviously travel varies wildly on productions depending on the home location of the crew and the script's demand for on-location shoots. In our hypothetical budget we have a total of $4.9M overseas crew travel during the traditional production shoot and we assumed a 50% reduction in that budget for Virtual Production shoot instead. Obviously this is a significant saving in costs but also in time for the crew and in greenhouse gas emissions (just one person flying business class return from Los Angeles to New York adds 2.5 tons of CO2 to the atmosphere[6] - an entire crew with equipment flying from LA to Eastern Europe can add thousands of tons of CO2 to the environment[7]).

Faster Shoot Times

As we've identified, a well organized VP Workflow shoot can speed up shot setup, pre-light digital sets, speed set resets and arguably save time in post processes too - such as editorial if the team is more confident in what they shot on-set is what they need. As Virtual Production is such a new technology, and experienced talent in limited supply, it's of course very hard to prove that each production will see speed improvements in the same range. Even though all productions are different we can look to predict future savings by using experience from those that have successfully deployed Virtual Production before. LucasFilm have publicly said they have seen 30-50% reductions in shooting time from their VP stages compared to traditional stages. Many of these LucasFilm shows are Sci-Fi and many use repeatable VAD assets so we're not confident that other productions should assume such similar gains. In our sample budget we have applied a 10% overall reduction in both shoot days which can obviously be modified up or down based on the type of shoot the user is modelling.

6 See myclimate

7 See Green Screen | Interreg Europe European initiative to track the environment impact of production

Quicker Picker Upper

Pickup shots are the bane of productions – last minute rushed shots often unbudgeted and especially challenging if they require reassembling cast and crew and travelling back to location or for sets to be recreated. However, if all the sets and locations are scanned with LIDAR and photogrammetry during regular production they can be recreated as digital assets on a VP stage for use during pickups (or promos, or sequels or as VFX references). Even multiple pickup shots are required spanning different locations then they can all be shot in one go, dramatically lowering pickup costs and time impacts toward the end of production. We haven't assumed any cost savings or implications for pickups on our sample budget but if line producers are adding a contingency for it, they can also counter the costs by providing some resources for these new 'virtual' pick ups.

Reduced "Post" VFX

The single largest line item change to our sample budget is a reduction in post VFX spend of $18m off our 'traditional' production budget. Of course this headline is misleading – as $15M of the VFX spend has not gone, it has simply moved into the VAD line item. There is still an expected reduction of $3M we forecast in our sample budget but there are other non-monetary benefits in moving this spend forward too. VFX produced at the end of a production are often impacted by time crunches and spending constraints that may limit the quality of the finished work and result in a 'good enough' mentality, or conversely budget overspends for rushed last minute changes. By moving the VFX spend forward – straddling pre-production and physical production, the VFX shots arguably have more breathing room to be refined and to get to higher quality, with less risk of creative compromise.

Licensed VAD Assets

We have assumed in our model that all VAD assets will be created for the show in question but we're also expecting a robust digital market to develop which licenses 3D digital environments, sets and scenes for use in Virtual Production. Our model does not include any examples of these at this time but for many familiar locations it may be less expensive and certainly much faster for producers to license digital VAD assets and have them dressed as if they were any traditional set for use in their production.

Digital Extras

We're also now seeing early development in truly digital extras that can be licensed and rendered in scenes as crowds or background characters to add ambiance and realism to a scene. Again, we've not modelled for those costs and savings versus traditional talent but it is an emerging space to examine.

3.3.3 - Savings across Slates/Series

While our model is built around a single movie production and we have demonstrated considerable benefits in cost/time for Virtual Production use cases, they are arguably compounded for shows that can re-use their digital assets.

For episodic shows that revisit the same locations a digital set is an ideal solution especially as it has close to zero storage costs and can be deployed in a number of different physical Virtual Production stage locations. If VAD assets can be reused for subsequent seasons, or asset creation even amortized across seasons, then the business case for a multi-season commitment can be improved still further.

The same is true of franchise slates and other shows that can reuse assets in subsequent productions. A percentage of the VAD costs cover asset building which, assuming the studio retains ownership of them all, can be reused in subsequent shows to lower production costs and speed pre-production.

3.3.4 - Other Media and Use Cases

Another out of scope area of benefit that is very production specific is the use of the VP stages and especially digital assets for use in other supporting media and forms. The dream of offline 3D VFX elements being repurposed into assets for use in supporting video games or VR experiences has been touted for years but the use cases are suitably different that the economies have never really worked out. But for Virtual Production the VAD will have created assets specifically for real-time rendering in a game engine and those assets are likely much more portable for use in supporting related transmedia projects in VR experiences, AR or promotional experiences, video games or other future forms of immersive entertainment. Again, we've not factored those benefits in because they are yet to be measured in sufficient example cases and likely will only apply to a subset of content produced in VP.

3.3.5 – Impact on Tax Incentives

Another area not deeply explored at time of publication is the impact of tax incentives on the Virtual Production ecosystem. This is because in many cases the regional and national incentives have not kept pace with the speed of Virtual Production innovation. For example, some regions offer tax and other incentives for offline VFX spend in their region, but it's unclear what happens when some of that spend moves to on-set VFX for Virtual Production. Will traditional VFX markets miss out on securing some productions because the digital skillsets are now needed on-set or in a different location? Will markets like Los Angeles that traditionally did not offer VFX incentives now start to support them to build a pool of Virtual Production artists in region?

Likewise some regions provide financial incentives for productions to shoot in their cities on the basis that they will economically benefit from large numbers of incoming cast and crew and the employment of local talent. Those same regions have not considered whether VP, and the use of licensed digital twins and digital sets, may negate the need for some of those productions to physically travel to their destination to shoot. We're not yet likely to see Downtown Abbey shooting in a digital twin of Highclere castle but one can see scenarios where smaller productions, pickup shots or 2nd Units will shoot from digital twins on VP stages rather than incur travel expenses. Should regional and national governments consider virtual licensing fees for shooting virtually? Do they even have jurisdiction to do so? These are questions that need to be addressed by regional and national governments if they want to keep pace with VP.

3.6 – Overall Cost Changes in Our Model

In conclusion, our sample model using our initial assumptions, demonstrates that our $100m budget 'traditional' production would see cost savings of $7.5M and a reduction in production schedule of 6 weeks. But of course, by changing the assumptions the model can be easily inverted to show higher costs and a longer schedule. Neither is right, neither is wrong. We are not trying to claim that a production using VP workflows will always save money or time because that would be a misleading claim, and of course often the objective is often not to save time or money – but simply get more of that spend on the screen where viewers can appreciate it. The purpose of the sample budget is to simply give the community something to play with and model their own assumptions and projects to examine the implications the production team should debate and discuss before deciding which shots and productions would benefit from Virtual Production.

4 - Qualitative Benefits and Opportunities with VP

In our budget **section 3**, we analyze many of the quantifiable impacts of VP – both in time and budget. However, there are many other benefits that are harder to define in pure economic terms but can be significant and certainly offer more artistic opportunities to the creative team. Here are 12 of them:

Source: Film LA

Preproduction/Planning	Major Market Talent Pools	Remote locations often don't have the depth of talent that's available in major media creation centers, VP allows productions more talent choice by keeping production local.
	Higher stage utilization	With set building happening digitally, production facilities and stages can shorten downtime between productions, and those productions can load in and start shooting faster – increasing utilization in markets like Los Angeles where 95% of stages are rented[8].
VFX Budget	Continuous Iteration	VP Workflows can mimic the typical animation workflow and offer a more efficient and continuous iteration/revision cycle so changes can be made in real-time.
Shooting	Lower Risk	With ICVFX and LED walls it's much easier for the entire team to know what's captured sooner so directors can see what their show will look like (versus guessing on a green screen) much faster resulting in less takes and reshoots.
	Team Collaboration	Filmmaking is a team process and with VP everyone on the team can see and work in real time with other departments, potentially opening a world of new creative options. The team can take risks and experiment together.
	Near instant resets, Less Downtime on-Set	With the ability to quickly reset or switch between environments, or rotate whole sets instantly, the team can shoot more iterations to give the director more chances to get what they want.
	God like powers	With photo real digital scenery, cinematographers can create their ideal lighting conditions and keep it that way without the stress of the sun or weather changing. Golden hour all day long.
	Less stress on actors	Acting in green screen environments is notoriously difficult for actors. VP technology that immerses them in a digital environment can potentially offer better performances in less time and with less stress on actors.
	Happiness of production team	Working on major productions usually comes with lifestyle compromises – time away from home and long hours. VP in their home city can offer the production team less travel, more family time and less work vs life challenges.
	Limitless Imagination	With 3D environments we can go anywhere and shoot anywhere and at any time period - including imaginary places that might be hard to build physically (eg. planets with complex atmospheres or multiple suns, or worlds made entirely of water!).
VFX/Post	Less Post Crunch	With less work piled into the postproduction window the production is less subject to the capacity constraints of VFX vendors and last minute creative and budget constraints forced by impending release dates.

# 5 - A Roadmap to Virtual Production

Virtual Production is not for every shot, sequence, or production, and it is, of course, an evolving area of both technology and workflow. It may be many years until we see the sorts of stable workflows, standards, and tools in VP that we have become accustomed to in offline VFX and post-production (if we ever get there). But, as we have explored, there are potentially great benefits in budgeting, timing, and other creative decision making such that all producers should be considering how they can try VP for some, or all, of their next production, to experience it for themselves. In this section, we provide some practical advice and guidance for those considering Virtual Production, as well as some cautionary tales about what may not work at this stage.

5.1 – Picking the right shot/production

No one wants to try a new technology or workflow on a shot/production where they risk failure or significant risk to the production. Selecting the most appropriate opportunity for VP, therefore, starts from accurately breaking down the script to identify the best VP opportunities. The new role of Virtual Production Supervisor is developing at studios (for use by all their productions) as a production team member, or even outsourced to the production by a vendor (e.g., Stage operator). That person can help breakdown the scripts with not just which scenes will be appropriate for VP, but also which type of technology would be best to use, which volume to do (build or rent), the volume size and scope, and recommending vendors for PreVis and VAD development.

When breaking down scripts, there are some initial shots which seem to lend themselves easily to VP and some to avoid at this stage of technical development:
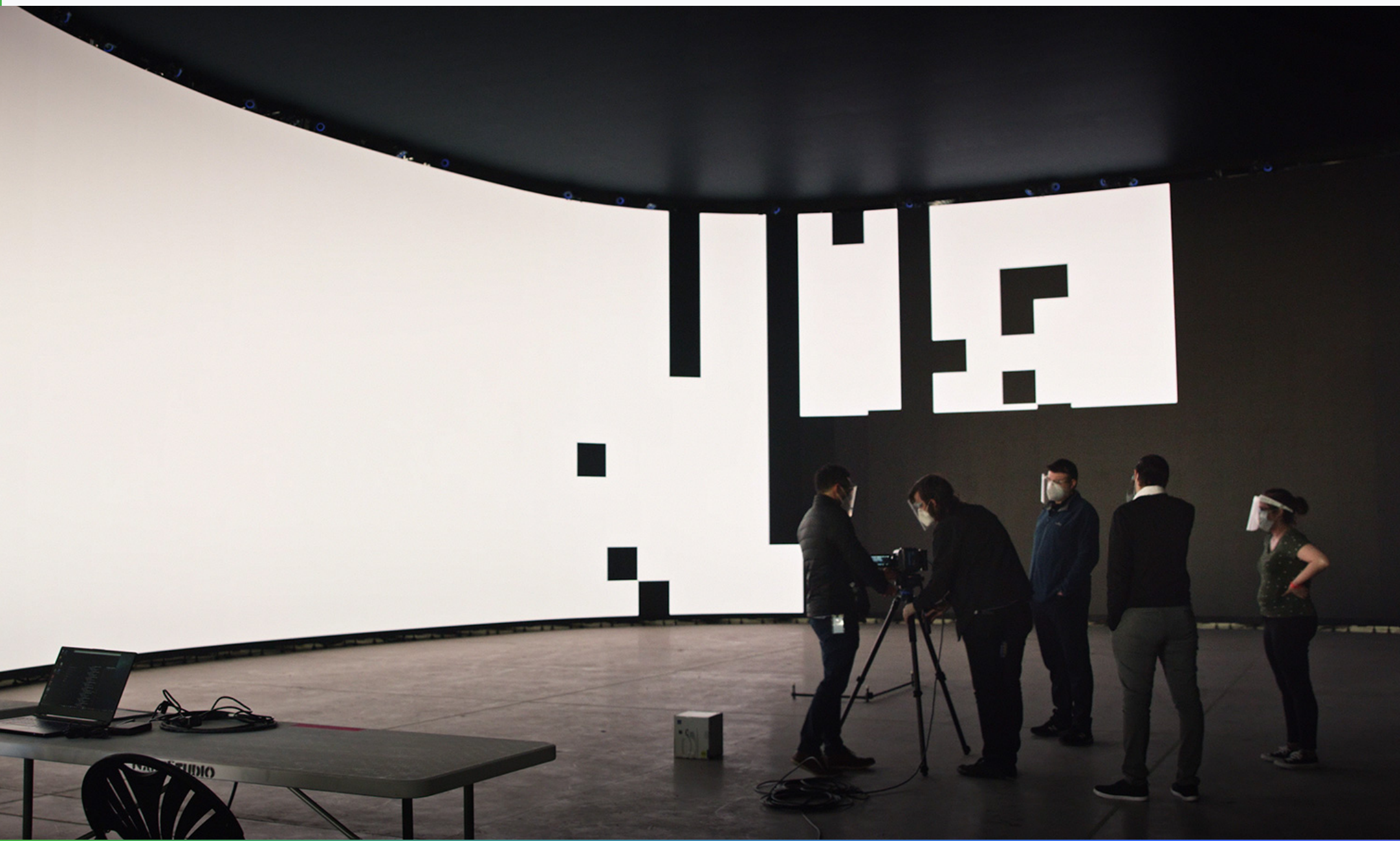
Good Shots for VP

Travel in cars, boats, planes, trains

Outdoor scenes with persistent light
(e.g.: sunrise/sunset or golden hour shots)

Actual locations that would
be dangerous to shoot in

Actual locations with access or
geographic constraints that will
make it hard to get cast or crew to

Little used sets or locations where
it would be impractical to travel to

Pickup shots that may use digital
twins of the original location

Indoor sets allowing environments/lighting to
be visible through windows and doors

Close-ups where characters eye reflections can
capture what is happening in the VP environment

Shots to Avoid in VP

Fast motion pans or long continuous tracking shots
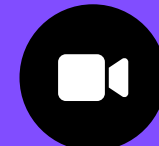
Significant background animation on the wall

Environmental shots that could be
dangerous (e.g.: real rain and water)
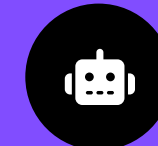
Scenes with digital characters
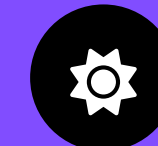interacting directly with
human characters

Really dark scenes where emissive
light from an LED backlight may
create too much light

Wide scenes/shots needing very
large practical set pieces

Significant/crowd stunt scenes

Midday daylight/high key sunlight

Considerations
when selecting Shows
and Shots for Virtual
Production

5.1.2 – Selecting 2D, 2.5D and 3D

While this is not a technical paper, there are critical budget and complexity decisions around which type of In-Camera VFX shots should be used. It could be 2 dimensions, full immersive 3D, or the middle ground – 2.5D. A quick summary of the complex technology is below, and there's much more information referenced in the LuxMachina "Dynamic Range of ICVFX" listed in the Further Reading section. This is to give a hint of the sorts of work a VP Supervisor will be doing while breaking down a scene looking to optimize quality vs. cost for each shot.

2D – Uses the LED wall or projector to present a video plate or digital environment that does not offer parallax during camera movements. It's the lowest complexity and cost for ICVFX and doesn't require camera tracking.

2.5D – Breaks the scene down into different layers, which could be CG or video plates but does enable basic parallax for added realism. Camera tracking is required.

3D – A fully digital environment requiring a game engine to render that offers the most flexibility as it can be dynamically changed during production and used from different angles and times of day. Requires camera tracking and a render solution that can display the required quality and the correct frame rate.

The game engine can render all types of assets here – 2D, 2.5D, and 3D, but the cost and timing implications are based on the time it takes to create the required assets for the more complex 3D scenes. If the audience will not notice the difference, then 2D or 2.5D may be better, but again, a good reason to PreVis the scene is to plan the camera tracks and understand whether the scene will benefit from full 3D.

Courtesy: LuxMachina

5.2 – Best Practices

In addition to matching the best shot to the correct technology, there's a wealth of expertise that is emerging from the early VP productions which we're including here. There's an immense amount of technical learnings but they are beyond the scope of this document and best addressed by other groups. This section will be routinely updated to keep pace with innovation, so check back regularly.

☑ **Secure a VP Supervisor Early in the Creative Process**

They can guide the planning and effective budgeting as soon as the initial creative executives are onboard.

☑ **PreVis and TechVis Shots for VP**

In addition to getting a head start on asset development that you'll need on the volume, these steps will also help to better plan to ensure that the physical production can take full advantage of the benefits of a VP enabled workflow.

☑ **Leave Enough Time for Pre-Production**

Some scripted TV shows will struggle to leverage VP workflows as they deliver scripts just a few weeks from physical production which, unless reusing digital assets/sets, will not leave time to build and plan the VP assets and technologies.

☑ **Consider Talent Availability Before Committing**

Unfortunately we still have a shortage of experienced creative talent who have worked on VP productions and those that have are in hot demand. So, before making commitments to studios and financiers, it may be worth ensuring that teams are available and can be contracted.

☑ **Plan the Creative Look of the Show with the DP / Colorist and Test Shots Before Starting Production**

This is to ensure that cameras, lenses, lighting, and equipment like LED volumes can create and capture the correct color space, dynamic range, and lighting for the look you are after.

☑ **Test Assets and Rendering on the Actual Volume Before Production Begins**

Assets should be checked to ensure they run smoothly on the selected hardware and volume before the entire production team arrives to start shooting.

☑ **Bigger Isn't Always Better**

Some huge volumes are available now, but they may not match the intimacy of the scene, or the production may benefit from more efficient use of multiple smaller stages to allow production to rotate through build/test, shooting, and strike days. The temptation may be to book the biggest volume, but sometimes it simply may not be the best match and several smaller spaces may be more appropriate.

☑ **Don't be Tempted to Cut the Lighting Budget**

Even though LED volumes can provide plenty of fill light and natural reflections, you'll still want on set lighting to add extra and targeted illumination.

☑ **Keep Time in Your Budget for Set Dressing / Turning**

Even though you may use digital assets on a volume walls, make sure you have enough time for both physical dressing of the set (there are still real floors!) and digital dressing. Even though VP can lower the turn costs between setups, it's still not immediate especially if you have complex foreground objects.

5.3 – Challenges with Virtual Production

As of time of publication, there are inherent risks and challenges with Virtual Production that we would be remiss not to mention. While VP is far from experimental and is rapidly maturing, these factors should all be considered before selecting productions, shots, vendors, or volumes to shoot any VP work on.

- [x] The VP Workflow continues to iterate as the pipeline is being constantly refined, and there's no "one size fits all" at this time. VP requires careful planning in pre-production to take advantage of the technology, and not all creatives will want, or be able, to make the transition to this much more careful planning. Production teams should be selected to ensure they can cope with potential changes in technology and workflow before, and even during, production. This iteration phase of Virtual Production will likely run for years to come and may never fully stabilize as the underlying VP technologies (real-time ray tracing, game engines, AI, and GPUs) are areas of accelerating innovation and disruption.

- [x] Traditional Production Pipelines are not "plug and play" - although there are some specific formats and standards in some areas of files, metadata, editorial, color, and sound which make certain tools and pipelines interoperable. Even though many of the VP tools (**Digital Content Creation (DCC)** tools like Maya, Unreal Engine, Unity etc.) can share digital assets, there are a myriad of additional tools, plugins, asset managers, and automation tools that are often customized by each vendor to get them to work together. This tends to mean VP productions now need experts on hand who can support the software development or modification to get a pipeline to work or to customize it for specific shows.

- [x] The LEDs used in current generation volumes are capable of creating fewer colors than modern cameras can capture, so DPs should test the volume they intend to use to make sure it meets their needs in production and post to create the sort of look that they want.

- [x] On-set rendering is very computer intensive and 3D models and scenes may need to be limited to ensure the frame rate is maintained. Real-time ray tracing uses AI accelerated denoisers and requires high-end GPUs to drive the number of pixels on these enormous LED walls. Some 3D assets built for offline VFX have too many layers of effects on top of them, or simulation elements, that will not run at continuous 24FPS required for use on a VP volume.

- [x] Even though an LED volume can create the visual perception of being in a different space or time, it does not recreate the ambient sound of being in person. Sound recording on a large volume can sound volumous and echoey, which may not match the style of the scene. Captured audio should be tested to ensure it can be matched to the real-world intent of the scene.

5.4 Build Vs. Buy Vs. Rent Decisions

As we have explored, running a VP stage and the associated equipment is a specialist's task and requires specialist teams of operators to run it all. That tends to lend itself to renting the whole package as you would a traditional sound stage but one equipped with a preexisting volume, rendering hardware, software, and operations team. For most individual productions, that's probably the most cost-effective way to go, but there may be some studios that are interested in buying some or all of the equipment to run their own volume, and some large productions that have specific or custom needs may be interested in building their own volume (using either leased or brought components). In this section, we'll provide a quick overview of the pros and cons of each approach.

5.4.1 – Renting a fully equipped VP Stage

This may be the most appropriate option for most productions as the number of VP stages in major media markets, although nowhere near as many as traditional stages, is increasing along with the choices of shapes and sizes. The VP stage operators can buy equipment in bulk and amortize it over more shows and provide talent to operate the stage and equipment, and they are more likely to have the latest gear and have a lower cost base than productions trying to build or buy themselves.

If considering renting a VP stage, here are some factors to consider:

1. Ensure the talent provided by the stage is experienced and has had multiple productions that are similar to yours.

2. Book sufficient planning time on the stage to ensure that your assets can render correctly before rolling in the full cast/crew.

3. Consider not just walls but also overhead LED panels or additional realism, especially in lighting.

4. Look for rigging flexibility – can you pop a panel out of the LED walls or ceiling to add a light (for fill or spot lighting) or for stunt rigging? Flexible stages allow you to keep your options open and not lock you in to a fixed space.

PROS OF RENTING A VP STAGE	CONS OF RENTING A VP STAGE
Operators who are experienced and expert in their equipment	Still a limited supply of stages in each key media market
Fast start-up	Stage or equipment may need to be reconfigured to meet your exact requirements
Low or no CapEx requirements	
Likely to have detailed 3D models for use in TechViz to help plan the production	
Likely to have latest equipment, fastest technology refresh cycle	

5.4.2 – Buying the equipment for a VP volume

There are scenarios where some studios or other large media organizations (VFX companies, broadcast networks) that may generate such volume of VP work that they can justify buying some or all of the equipment required for a VP volume. This could include buying brain bars, other compute equipment, LED panels and so on so that a VP stage could be deployed within multiple other stages or moved to where the productions most require it.

This will obviously be a large capex expenditure so any organization venturing into buying needs to be comfortable they'll get the utilization they expect and are buying the correct equipment. Of course the costs are not just CapEx – there are people needed (either contract or full time) that will be required to design, run and deploy the equipment. Also as Virtual Production technologies are evolving fast there is a very limited payback window – the equipment is likely to be out of date in 3-5 years and need updating. In addition, many of the components for Virtual Production are in high demand in other industries (LED panels for example in tradeshows, live events and conferences and GPUs in everything from cloud computing to Artificial Intelligence) so buyers may not get component availability or the best prices if buying for just one location and/or use case.

PROS OF BUYING VP STAGE EQUIPMENT	CONS OF BUYING VP STAGE EQUIPMENT
Potentially lower costs than renting on a per show basis, if spread across multiple productions	High CapEx (and still need some OpEx to include operators who can run and maintain the equipment)
Can generate income by renting the equipment to other productions/studios and industries	High equipment obsolescence means a 3-5 year refresh cycle
	Still need to move and deploy equipment on a stage

5.4.3 – Building a VP Stage

This may be related to buying the VP equipment, but in some cases an operator may want to build a VP stage but not own the equipment (most operators lease their LED wall panels). This may not be the most appropriate option for most productions but may be considered by large studios producing large volumes of content (e.g., franchises, repeating TV shows) that decide they want to build and run their own stage. In this case, they could decide to buy or lease the equipment required, but there are other considerations, including can they justify the utilization that will be required to pay back the investment – not just in CapEx but the ongoing OpEx to run the volume operations team. We've seen a number of major media organizations build their own VP stages (and some shut them down again) with the intent of experimenting with the technology, the required workflows, and to better understand the economics of VP. In many cases, they paid a specialist company[9] to design, build, and operate the stage, so they can focus on the creative workflow implications.

Regardless, this is a major investment and can only really be justified by a strong business case that the stage can be utilized for 3-5 years with many productions or that the investment is funded for creative reasons with the intention of being a loss financially.

PROS OF BUILDING A VP STAGE	CONS OF BUILDING A VP STAGE
Control of booking time and always have available capacity	Large CapEx or OpEx (if renting equipment)
Learn and iterate on VP workflows to understand most efficient systems	Stage or equipment may need to be reconfigured to meet exact requirements
Attract and retain talent interested in exploring VP technologies and workflows	High equipment obsolescence means a 3-5 year refresh cycle
3D assets and pipeline can be optimized for a specific volume	Opportunity cost of removing a traditional stage from circulation
Build close relationships with VFX vendors who want to integrate the volume into their pipelines	Stage may not be in the right physical location(s) for each production
	Correctly sizing the stage for all potential titles and shots that it may need to support

[9] E.g., LuxMachina Consulting - Lux Machina (luxmc.com)

6 - Conclusions

At the time of publication, this guide was up to date with the latest in virtual production, but next week it will be out of date. The space is evolving so quickly, with the bleeding edge healing to be merely the cutting edge and the experimental becoming commonplace. But, as with other technology shifts in our industry, for example when we moved from film to digital, there were innovators and laggards, but ultimately the entire pipeline became digital (whether you shoot on film or not). The basket of VP technologies and real-time rendering represent the same potential sea change in workflows and the broader macro environment as with the migration to digital. We're likely to see new and competing formats and approaches, new vendors, and new tools and potentially we'll lose some legacy ones as we did with film. But, the creative choices that are opened up, the potential for entirely new forms of entertainment, and the opportunity to create better content at lower cost justify the tumult that may be created. Some people and organizations may elect to sit on the sidelines while some of the kinks are ironed out, but they run the risk of coming in too late and having too far to catch up in this constantly evolving world. The kinks may never be fully worked out, as they aren't in digital capture and postproduction, but at some point, everyone needs to jump in and try it for themselves.
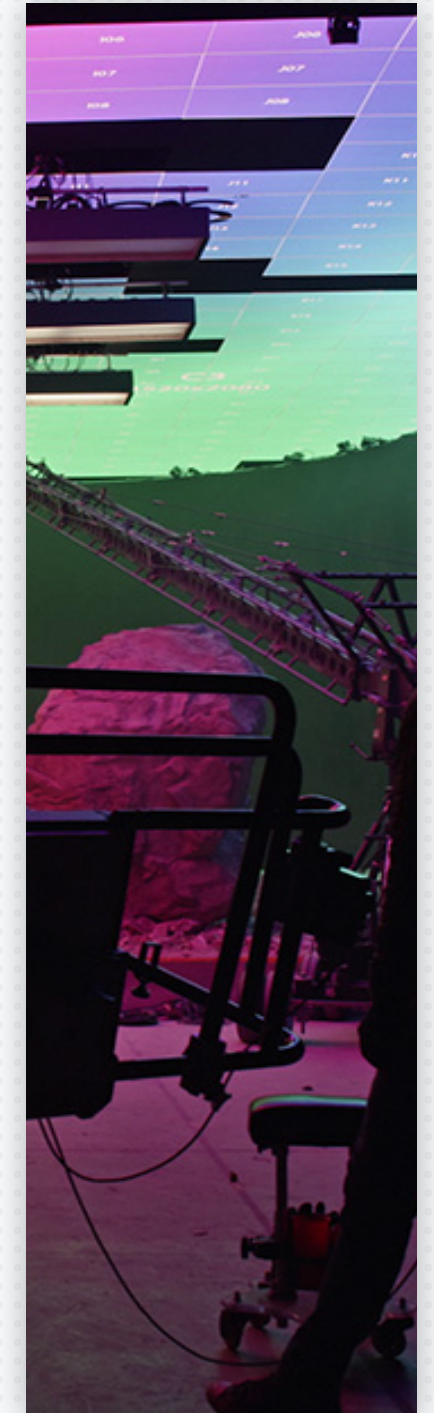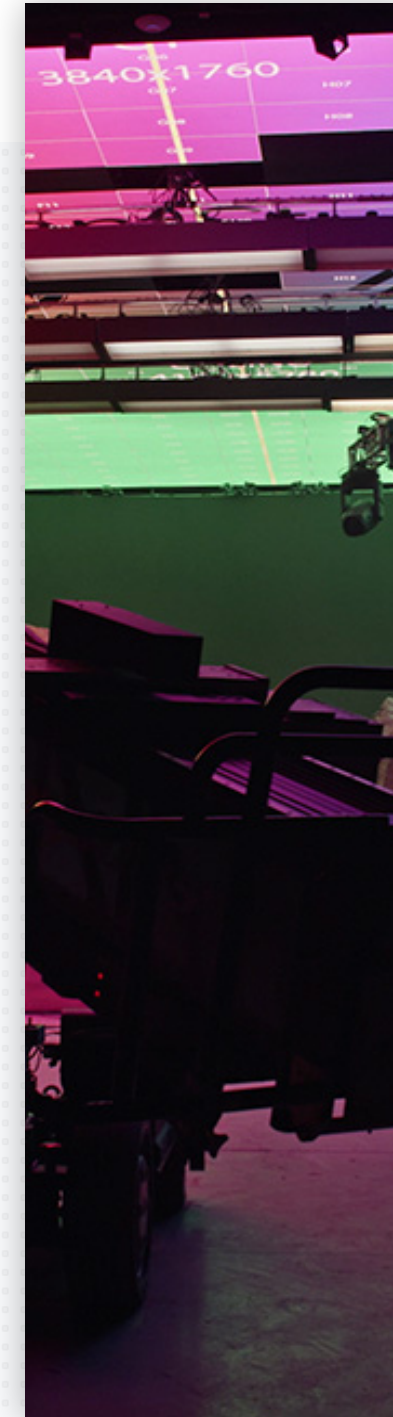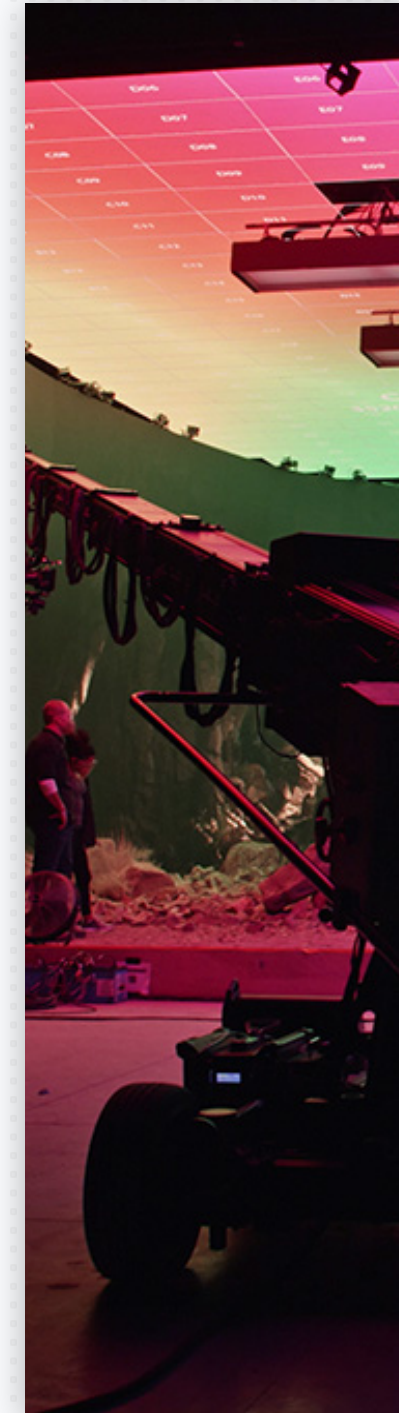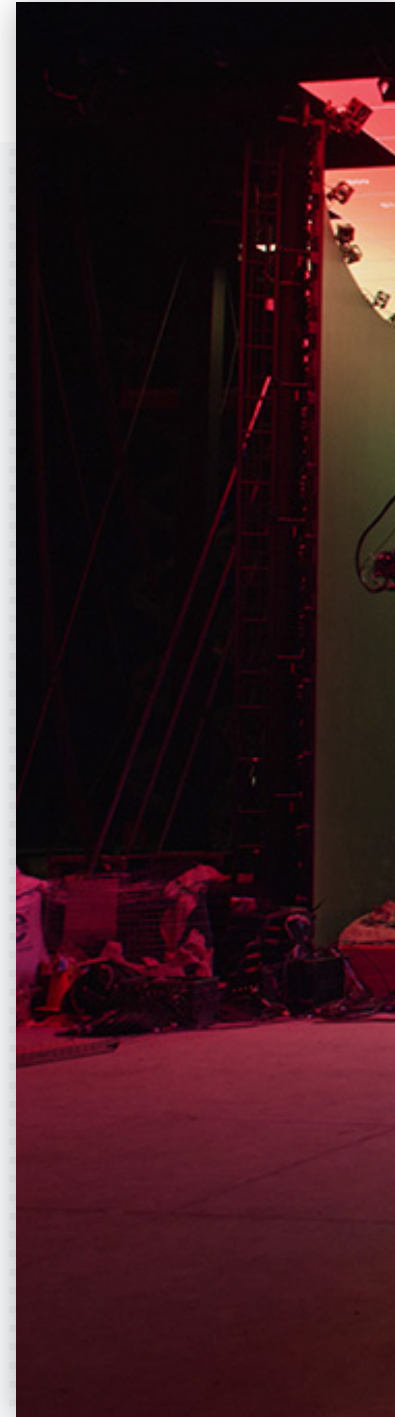
In this paper we've reviewed both the benefits and challenges with virtual production and looked at the workflows and economics. Our conclusions are 4-fold:

1. Virtual Production Technologies are no longer 'experimental' and have reached a level of maturity where there is stability, choice, and sufficient case studies to justify the claims of cost savings and time efficiency.

2. More than just shooting against an LED wall, the movement to filmmaking enabled by the full range of Virtual Production Technologies is inevitable at this point, but it is the combination of them into a new Virtual Production Workflow which offers the most creative and efficiency gains. That iterative, collaborative, and dynamic workflow enables real-time decision making which offers creatives more choice and flexibility in their shows, while lowering risk and stress.

3. Film producers and studios should be considering using the technology on their next productions. Not every shot and every show, but certainly enough to start the educational journey and build trust.

4. However, this new approach requires diligence in planning and preparation to enable the gains – especially in allocating time and budget during pre-production for asset creation. Each production team needs to explore the technology itself to see how it works for them, but they should do so with experienced VP stage operators, VAD team members, and a VP Supervisor.

We look forward to seeing what the community can create with the Virtual Production tools–stay in touch!

For those wanting to learn and experiment, there are many great vendors who are willing to work with filmmakers and producers on their journeys. The guilds, academies, and film schools are all adding educational programs and peer groups, but, of course, the best learning comes from actually 'doing' with on-set experience.

As this space is evolving so fast, Entertainment Technologists and NEP Virtual Studios are committed to keeping this whitepaper updated with regular news and modifications. Find out more by following **Entertainment Technologists Inc: Overview | LinkedIn** or **www.NEPVirtualStudios.com**.

7 - Acknowledgements

This paper would not have been possible without the contributions of the following expert contributors whose insights have been generously given.

8 - More Resources

For those looking to deepen their knowledge of Virtual Production technology, and tools and workflows, here is some additional information that may be useful.

"The Dynamic Range of ICVFX" by LuxMachina

LuxMC The Dynamic Range of ICVFX (adobe.com) - An easy to read guide with samples, best practices and examples of 2D, 2.5D and 3D capture on an LED volume

Virtual Production Environmental Impact Study

Workflowers.net

The Reality of Virtual Production

Feb 2023 Issue of TV Tech (Pages 10-12)

How Virtual Production is Helping Cut Cost and Reduce Carbon Footprint

Variety.com

Virtual Production Glossary

VPGglossary.com

"Virtual Production Field Guide" by Noah Kadner Presented by Epic Games

Volume 1 and **Volume 2**

Classes For VP by CG Pro

BecomeCGPro.com/classes-for-film - Virtual Production classes for Producers and artists looking to build expertise in the new VP economy

Questions?

Get in touch with us at VP@EntertainmentTechnologists.com