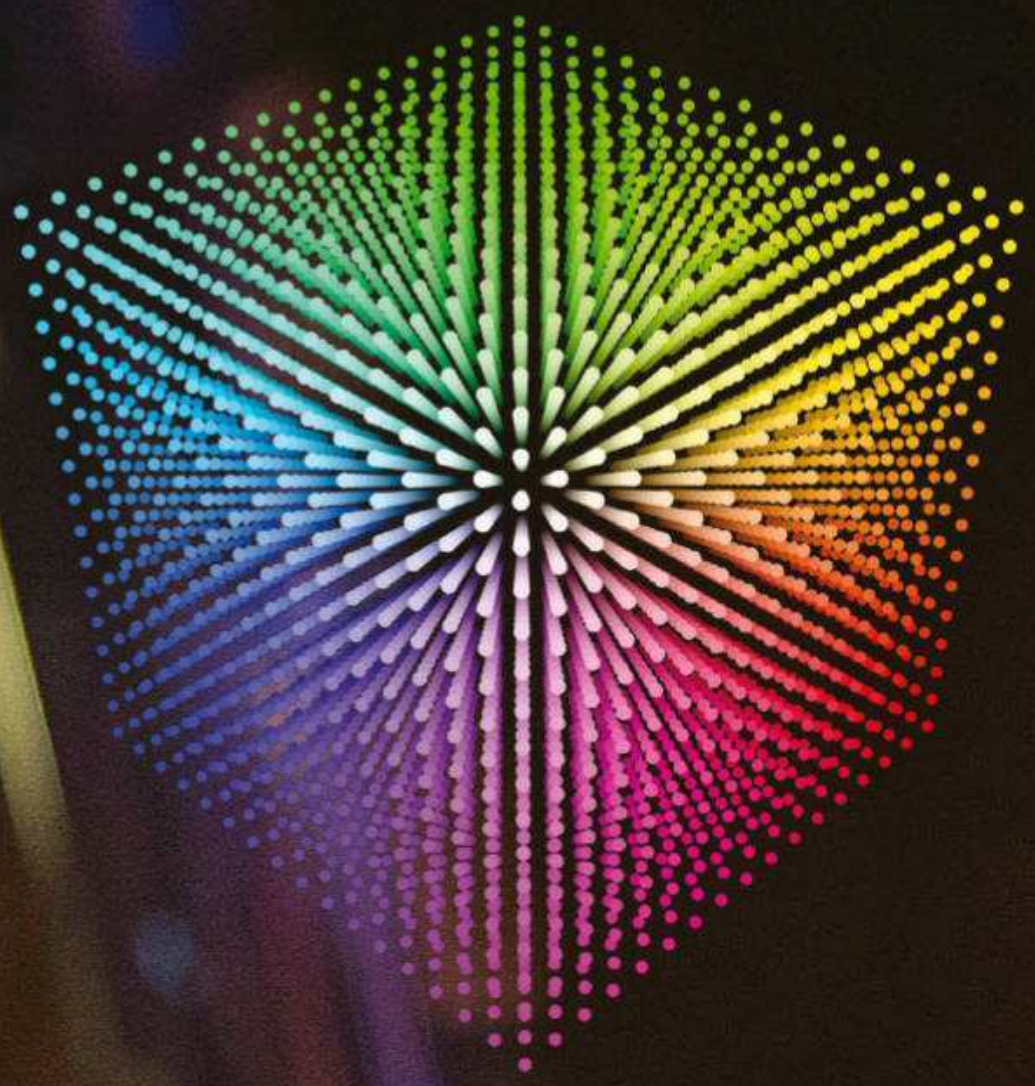


THE ACE OF COLOUR MANAGEMENT

ACES, the colour management system hailing from the Oscars has spread across the VFX industry with great success, Greg Barta from sciVfx describes its basic principles with 3D visualisations

The nature of the tasks that 3D artists usually do is kind of a mixture of many art forms such as photography and painting. Painters start with a blank white canvas and compile the wide range of colour values of reality into their much narrower palette to achieve a compelling image in its viewing environment and lighting. They can achieve brighter colours than the white of the canvas using special pigments, but it does almost nothing if we hang that painting on the wall of a movie theatre with the screening light settings. However if we put it in front of the screen and light it with the pure white of the projector, this can make a good painting a quite impressive experience. Besides having a multi-thousand watt light source in the projector that defines the dynamic range in this case, the wide range of compounds, origins and different manufacturing processes of the paint pigments provide the rich colour palette for the painter to create scenic paintings. Filmmakers have just three colours, but the features of photochemical processes, like cross-talking, give them a unique, cinematic look. In contrast, today's digital imaging tech don't just use only three colours, but these are just data most of the time and converted to an image signal when displayed.

THE PROBLEMS

Every 3D artist probably remembers a time when they achieved a good-looking render then changed some basic parameters, like exposure, and the new result ended up looking a bit odd. There could be many reasons for this but the most obvious problem is the lack of proper colour management. In this case, artists tend to use physically-inaccurate values to compensate for the inappropriate rendition of the colours on the display, which is the worst idea when working with physically-based renderers.

The 3D/CG community woke up a long time ago and realised that directly displaying the raw scene colour values on the display is a technical glitch, thus it is normally compensated with the well-known gamma correction.

However the presence of a proper colour management system was still the privilege of

LEARN HOW TO SET UP **ACES** IN **HOUDINI** FOR PRODUCTION IN **ISSUE 125**!

Guardians Of The Galaxy Vol 2 used ACES colour management

> “Today’s display technologies have a maximum achievable brightness, which are orders of magnitudes lower than in reality, and the saturation of each colour component limits the gamut”

VFX houses until recently and is still not a widely adopted practice.

Our culturally-affected collective colour memories strongly rely on photos and paintings we’ve previously seen, it can make the colours of a raw – and even gamma corrected – 3D render unfriendly. There are also more basic principles, which affect the perception of the image on a display. Today’s display technologies, even HDR monitors/TVs, have a maximum achievable brightness, which are orders of magnitudes lower than in reality, and the saturation of each colour component limits the gamut. Thus, we should reinterpret all or almost all the colour values of the scene properly into the dynamic and gamut range of the display to get a compelling image. Firstly we set the exposure of the render – or worse the lights – however this is just a multiplication of the RGB values. With such simple maths, a daylight scene tends to be dim, flat and washed out on our relatively dark display. Luckily the nature of photographic processes usually compensate for these automatically and we get a compelling image at the end. If we use digital cameras, the camera’s raw developer softwares and colour-grading suites offer similar opportunities.

Most renderers have advanced colour-tweaking capabilities like highlight compression and LUT import but these are still far away from the capabilities and benefits of a standardised colour-management system like ACES.

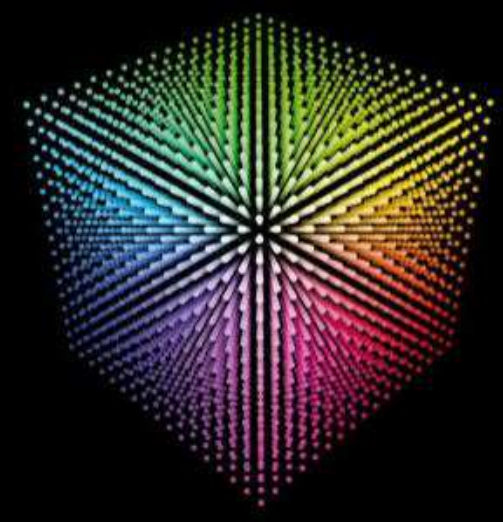
GOING FOR GAMMA

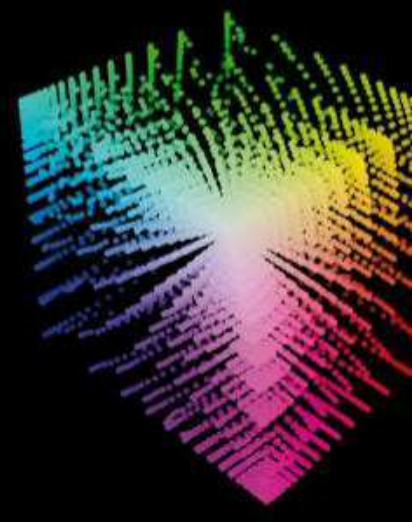
In CG the gamma means the power function of how computers encode the colour data, but its past traces back to before the era of computers

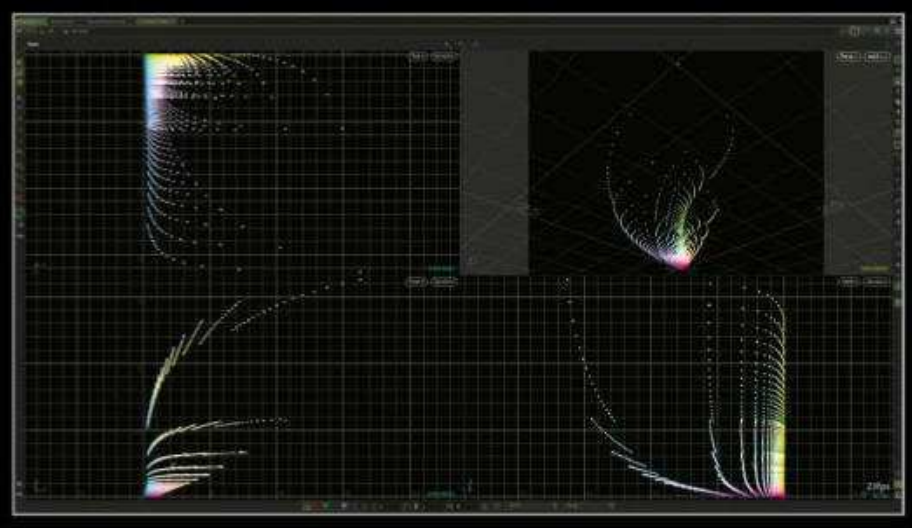
Gamma originated from the photochemical era of photography and shows the relationship between the original incoming light values and the darkening of the film emulsion – the density. Thus we can alter the gamma of the final result with different techniques. However the crystals in the film emulsion are nothing to do with maths and their sensitivity to the light isn't linear nor expressible with the maths power function, which is the gamma value in digital imaging. Additionally the saying is that painting and film-based photography use subtractive colour models. If we put layers of evenly exposed film frames on top of each other and each of them halves the trespassing light amount, then two layers will mean a quarter light, three means one eighth and so on. This is a non-linear multiplicative situation, and not simple subtraction. Summing all of the features of the process, the density of the film becomes more like an S-shaped curve in the function of the exposure level at the capture side, which is not linear but logarithmic.

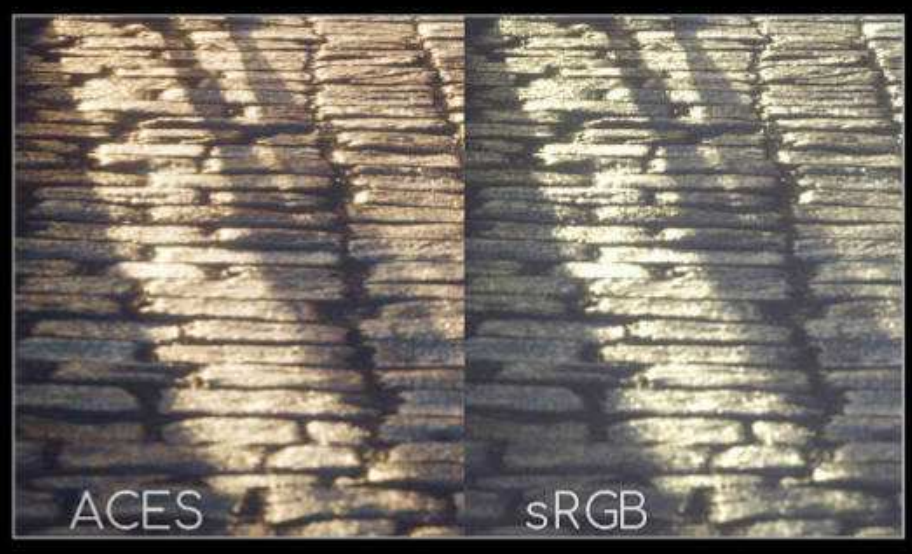
In video and digital imagingm CRT monitors had special response characteristics to the input signal, the gamma curve – which has to be compensated to more or less have physically-linear gradation at the end. LCD and other contemporary displays adopted this because it is a benefit – there are more digital signal steps in the low and mid-tones than in the highlights, which is in correlation with the sensitivity of the human vision.

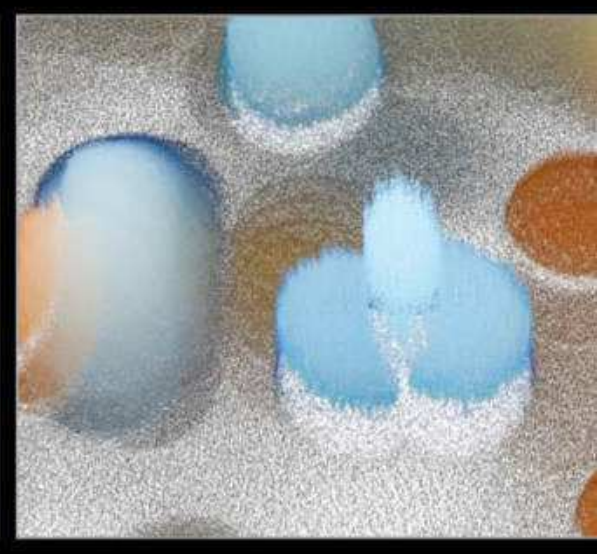
CHECK OUT WHICH MOVIES USED **ACES** ON IMDB
IMDB.TO/2BU8KXV











The story of ACES traces back to ILM where the EXR file format was developed. Scene-linear based image storage and processing pipeline requires a proper colour-handling system, especially because at that time most productions were shot on film mixed with digital camera inputs. Additionally most VFX productions involve multiple vendors, and each with their own colour pipeline can cause big trouble. In late 2004, the Science and Technology Council of the Academy of Motion Picture Arts and Sciences (AMPAS) formed the Image Interchange Framework committee. During the next decade engineers, scientists and artists from around the globe developed a colour-management framework suitable for everyone in the motion picture industry.

In late 2014 they came out with ACES 1.0 and released a standard along with specifications and recommendations.

Before its official release, brave creators utilised the pre-release versions of ACES in some VFX-heavy, big-budget productions like Blomkamp's two films, *Elysium* and *Chappie*. SKYLAB, the post-house of both films developed an ACES-based colour pipeline across the entire production, which was also used at Image Engine and the other VFX houses.

> "In late 2014 they came out with ACES 1.0 and released a standard with specifications and recommendations"

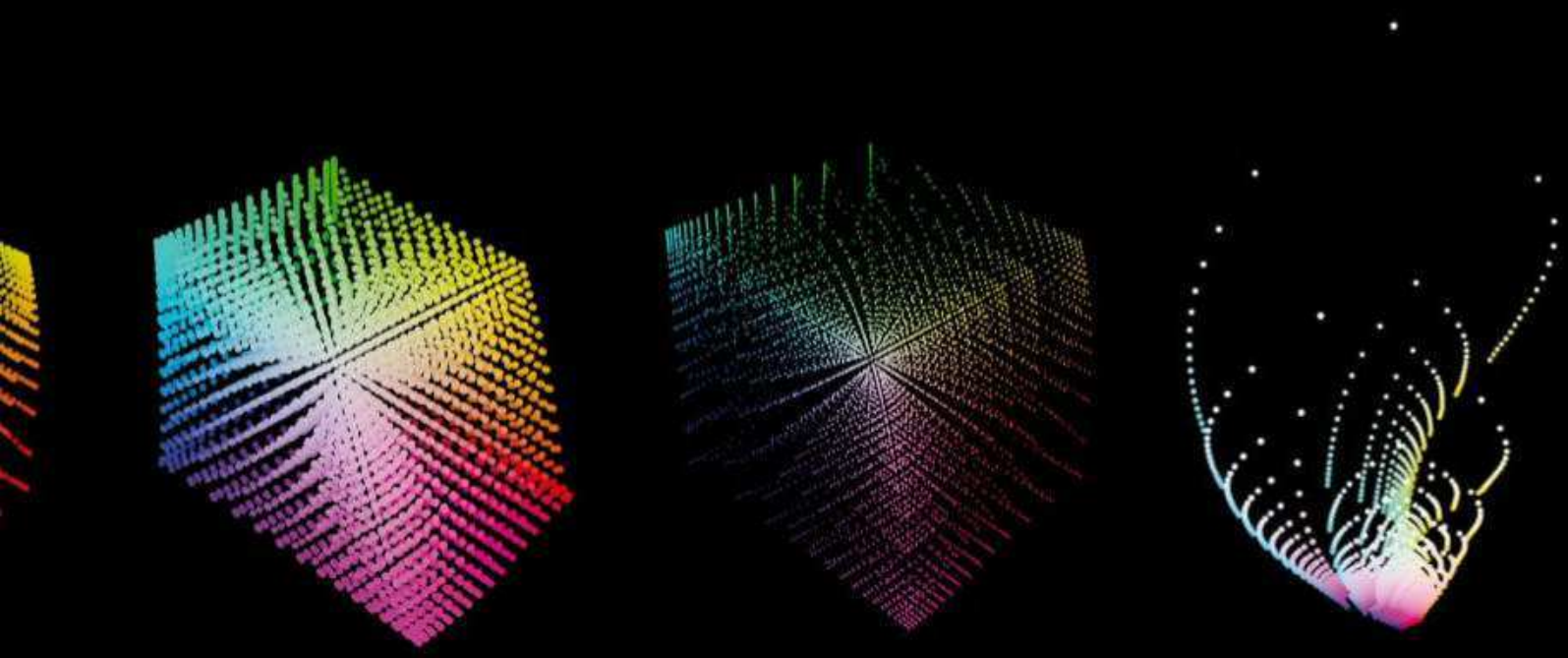
It removed repetitive tasks like tweaking the lighting, comp and grade shot-by-shot and at every iteration, which was almost always necessary before. They called this approach 'meaningful color'. It allowed artists to focus more on the creative decisions, and also brought the lighting work a step closer to a cinematographer's experience.

As ACES spread, more and more people have been using it, not just for VFX but for the entire production. The high-end digital cameras (Arri, RED) and DI/grading systems are already supporting it. The count of finished ACES-based productions is in their hundreds and is rapidly growing to include commercials, music videos and TV series. The recent big budget ones are *Black Panther*, *Avengers: Infinity War*, *Ant Man And The Wasp*, to name a few.

ACES also has a good future in the world of interactive content like video games and VR because the default colour management in Unreal Engine (from version 4.15) is ACES based, as well the colour correction module in the Post Processing Stack in Unity.

ACES EXPLAINED

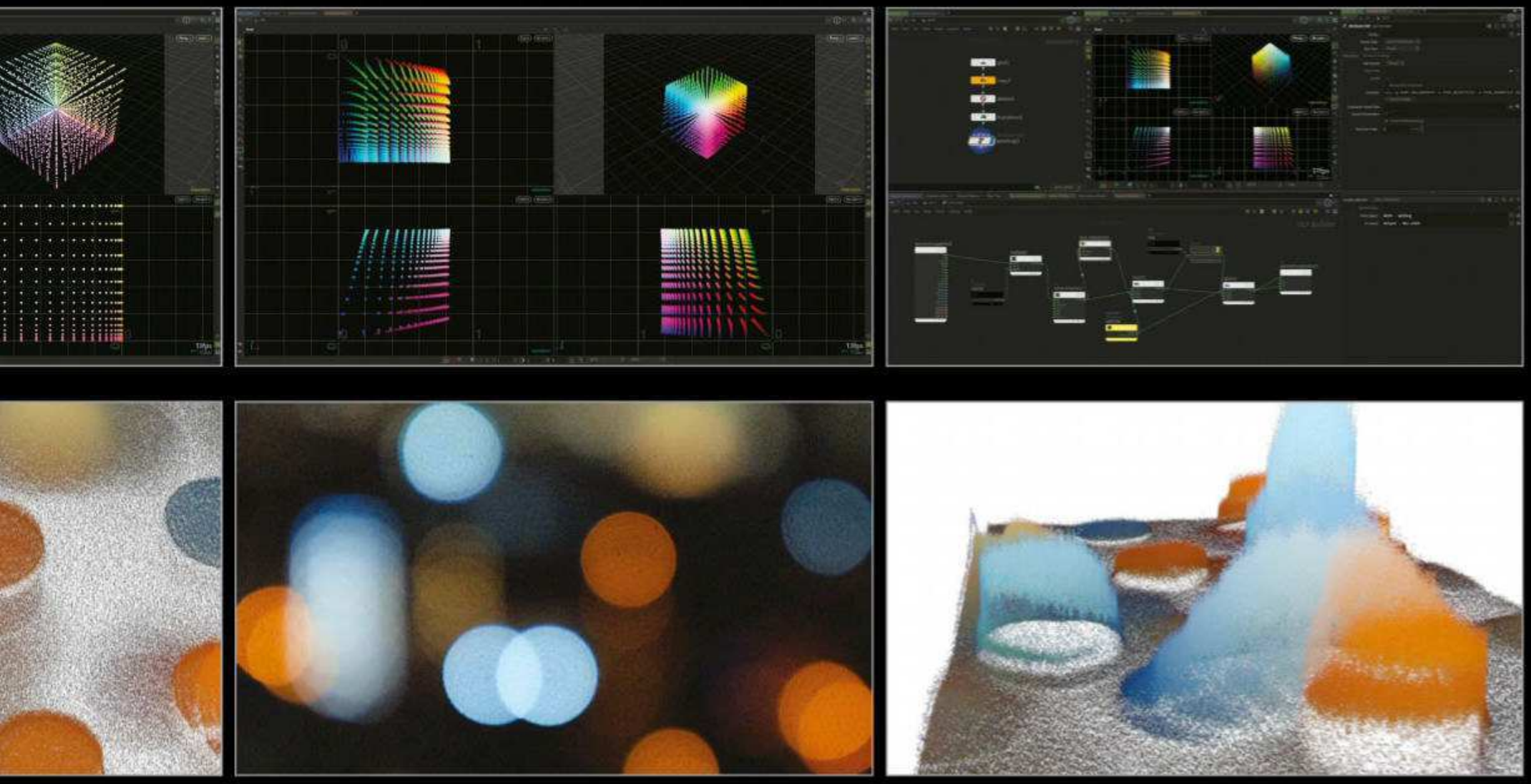
From a 3D artist's point of view the most interesting parts are the advanced colour management capabilities and the easy image interchange with other artists, departments or studios. ACES keeps the image data all the way



Top: The visualisations here show the ACEScg colour space, each RGB value is represented as coordinates of the 3D space

Middle: We can see how image data is transformed through the different steps and directions in the ACES pipeline

Bottom left: Benefits of a 3D render: highlights are compressed without sharp clipping and saturation depends on lightness



down to the pipeline in scene-linear format but on the display side reveals it photometrically correct and in a compelling way, solving the problems we mentioned before.

Thus, the ACES colour pipeline has two main parts: the scene-referred linear colour space where we store and process the image data, and the display-referred where we get the picture prepared for display and final delivery. To keep it simple, the colour transform from scene-linear to display has two steps: the first is the RRT (Reference Rendering Transform), a common step for all kinds of displays. This is the predigestion of the linear data and includes the S-curve and other modifications which makes the image compelling but display neutral. The second step is different for each kind of displays because they have different characteristics and viewing environments like a reference HD monitor in a post house (Rec709) or digital cinema projector (DCI).

ACES is based on the commonly used RGB tristimulus colour model with defined and fixed

> “This is the predigestion of the linear data and includes the S-curve and other modifications”

colour primaries – the coordinates of the RGB triangle in the well-known CIE horseshoe diagram. The recommended and common practice in VFX is to use the CG version of the primaries (ACES Primaries 1: AP1 or ACEScg) as the working space, because these are very close to real colours and are evenly distributed along the spectrum, thus the math behind the renderers and compositing softwares work well with this, without any special care.

However the original ACES standard ones (ACES Primaries 0: AP0 or 2065-1) are virtual – outside the horseshoe – to cover all the visible colours with just three primaries. The big screen deserves big colour gamut. The main purpose of this is to be future-proof. The spreading UHD and HDR standards and especially the RGB laser projectors have much wider colour gamut than the HDTV/sRGB.

The official file format of ACES is half-float, 16-bit EXR with the AP0 primaries, but most of the VFX houses use the ACEScg (AP1) for storage as well.

We can easily use textures and matte paintings that are not made in ACES as there are input colour transforms for them.

There are also input device transforms for various professional cameras (IDTs) to directly import raw footage and automatically match their colours, which is a dream for compositors and colourists. ACES is not a colour-management software or plugin, rather a standard, but many implement it in their softwares and it is also available as a free OpenColorIO (OCIO) package, which is supported by most CG software.