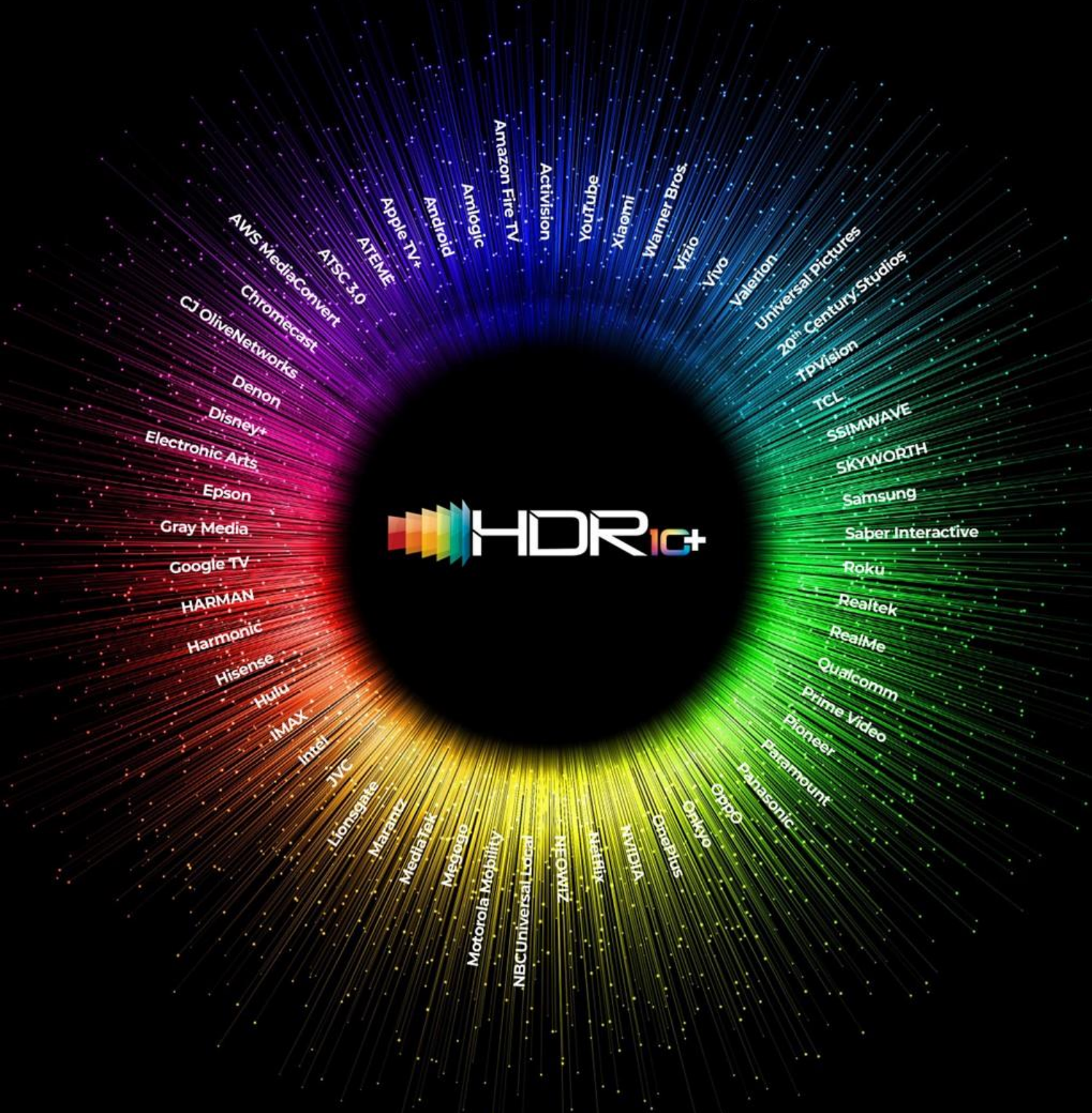
HDR10+

Understanding the Ecosystem



Presented by HDR10+ Technologies, LLC

Introduction

In the digital age, the choice of consumer displays and projectors has never been better – and never more potentially confusing. Exciting new device technologies and distribution platforms are jostling for attention at the same time that video content itself is undergoing a dramatic transformation called Ultra High Definition (Ultra HD).

A new benchmark for high-quality video, Ultra HD enriches entertainment with a suite of powerful advancements:

- **4K and 8K resolution** are delivering much greater picture detail than ever before.
- **Wide Color Gamut** enables content creators to produce and viewers to experience a greater range of hues for more vibrant images.
- **High Frame Rates** present fast-moving sports and action with unprecedented smoothness
- **High Dynamic Range (HDR)** delivers greater impact via darker "darks" and brighter "brights" along with more nuanced gradations for better delineation of on-screen shapes.

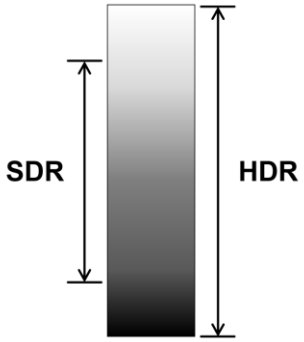
The global standards-setting body, the International Telecommunication Union (ITU), established this next-generation technology via two landmark standards: ITU R-BT.2020 for Ultra HD and ITU R-BT.2100 for High Dynamic Range.

Although all of the technical advances under the Ultra HD umbrella are important, HDR is critical. While production professionals and A/V enthusiast publications understand the significance of HDR, it has not achieved awareness on par with its transformational contribution to picture quality. With nearly a half dozen formats vying for attention, HDR10 has become the de facto standard, utilized across the entertainment and electronics industries. HDR10+ builds upon this robust ecosystem for even higher performance across a wide range of applications.

This paper explains the powerful advantages of HDR – and shows how the HDR10+ ecosystem fully delivers these advantages.

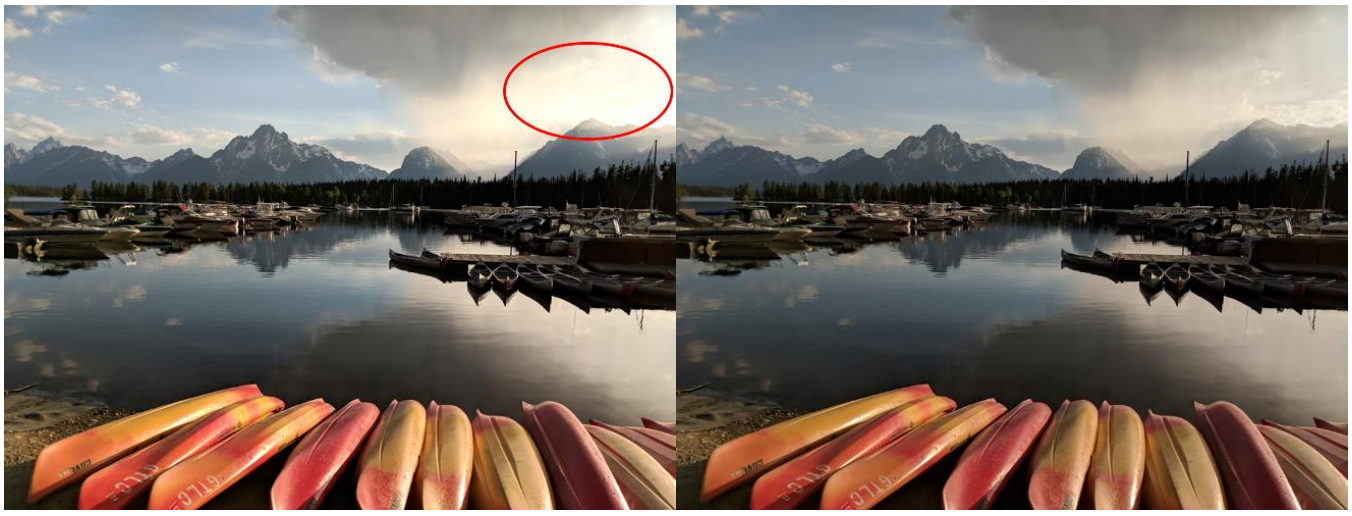
The importance of High Dynamic Range

After decades of Standard Dynamic Range (SDR) television, HDR represents a breakthrough. Consumers, if they're aware of HDR at all, typically associate this technology with "brighter" pictures, which are measured in units called "nits." While brightness is a major aspect of HDR – it is only one part of the story. HDR is really about the entire dark-to-light range of tonal values, what cinematographers call "grayscale." HDR enables us to see the entire grayscale: not just the highlights, but all the shadows and all the subtle gradations in between.



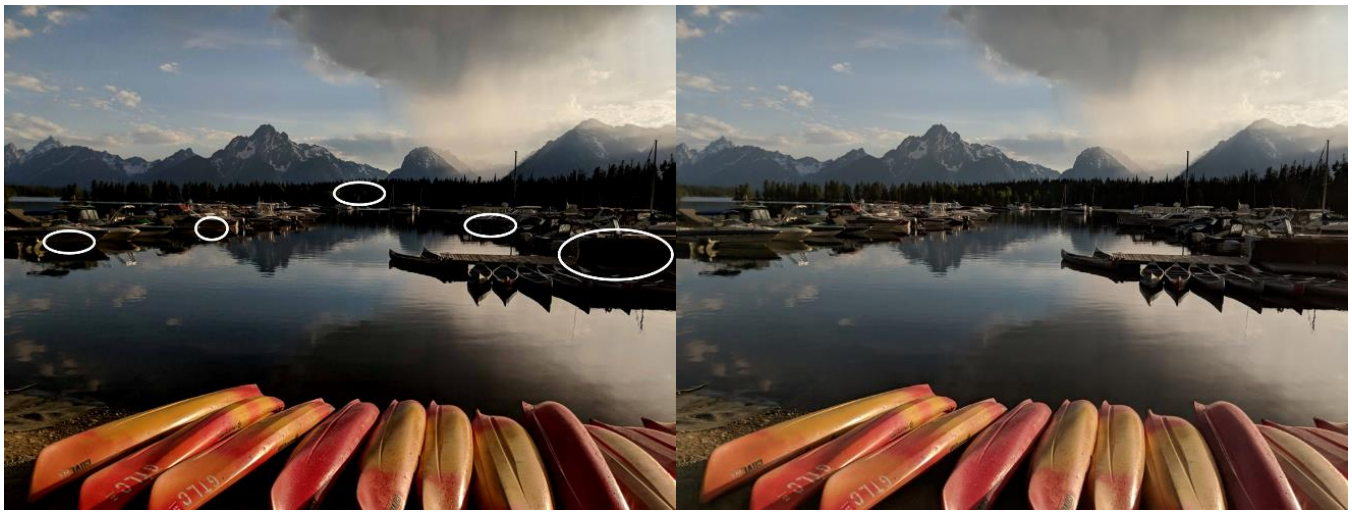
Today's cameras capture deep shadows and bright highlights. SDR can't reproduce them. HDR can.

HDR starts with better reproduction of the grayscale extremes: deeper blacks and brighter highlights. You also get better detail in the brightest areas of the scene – without the losses that cinematographers call "blown out highlights."



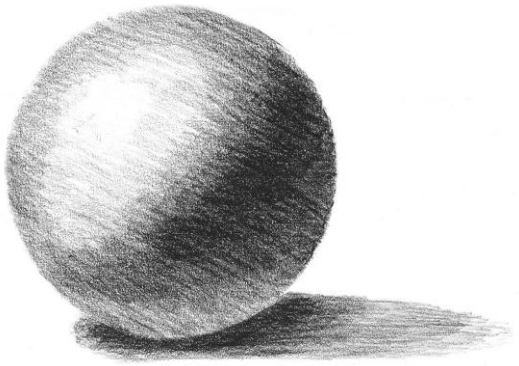
In the simulated SDR image at left, the circled highlights are "blown out." The simulated HDR image at right retains significant highlight detail in the clouds.

Additionally, you get better dark areas – without the information loss called "crushed shadows."



In the simulated SDR image at left, the circled shadow areas are "crushed." The simulated HDR image at right retains significant detail in the boats, pine trees and the dock.

You'll also see better expression of the "middle grays" that give on-screen objects their apparent shape.



Middle grays help us interpret on-screen objects, here defining the curvature of a ball on a flat surface.

The experts agree

The profound benefits of HDR are well supported by independent research. For decades, vision scientists have understood that the perceived "sharpness" of television pictures is created not by resolution alone, but also by contrast.[1] In carefully controlled experiments, viewers perceived HDR as substantially better than SDR. These experiments confirmed

[1] Schade, Otto H., Sr., "Electro-Optical Characteristics of Television Systems," RCA Review, 1948

HDR to be one of the most beneficial features of the UHD standard.[2] Independent journalists and equipment reviewers have agreed, consistently describing HDR as "brilliantly realistic," "a huge advancement," "like night and day," "impressive," and an "entirely new level."

In short, HDR is a giant step forward delivering a better, more engaging entertainment experience across all types of screens.

Creative benefits of HDR

Dramatically better picture quality in consumer displays is just half of the story. To the creative community, HDR goes directly to the heart of visual storytelling, enabling a greater range of expression. Careful control of grayscale's light and shadow helps to establish mood, convey realistic skin tones and identify what to look for in a scene. In fact, grayscale is so important that for each individual scene, movie crews typically set up a unique configuration of lights, reflectors and diffusers to achieve just the right effect. Moreover, the director and cinematographer continue to dial in grayscale values during postproduction, via color correction and mastering.

By expanding and refining the grayscale, HDR dramatically improves movies, TV programs, and videogames. HDR transforms the viewing experience, making it more involving, dynamic, and closer to the creative intent. In short, HDR is "entertainment as it should be."

[2] Ebrahimi, Touradj: "HDR video quality assessment by full paired comparison," presented at Technology Summit on Cinema, NAB 2014, https://www.youtube.com/watch?v=H35yFAhnbXY

The development of HDR10

The foundation of HDR was the establishment of the ITU R-BT.2100 standard, which caused an explosion of interest in compatible content creation and consumer products. In response to these developments, the trade group now known as the Consumer Technology Association (CTA) adopted an easy-to-implement configuration for HDR compatible displays. Announced in 2015 and built on the ITU standards, this was called the "HDR10 Media Profile" because it incorporates 10-bit grayscale quantizing.

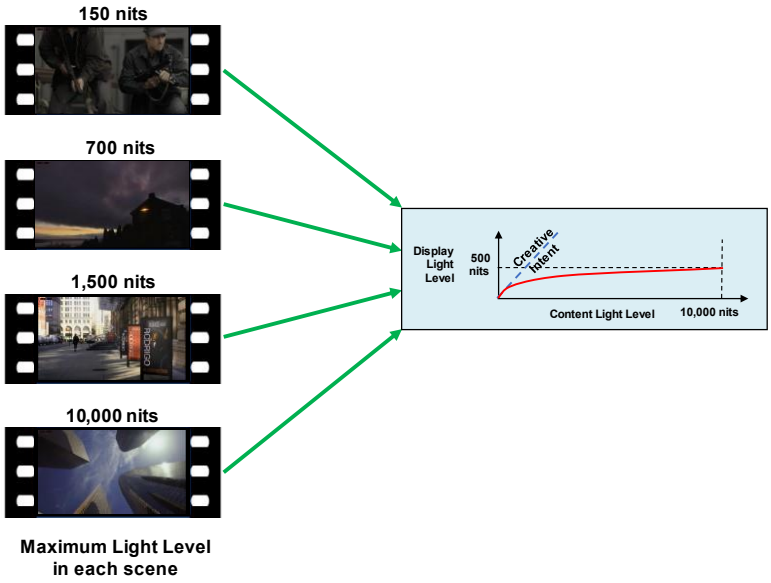
In addition to compelling picture quality, HDR10 provided other benefits:

- Any content creator can work with it.
- Device manufacturers can easily implement it.
- It's an open format that requires no licensing.
- No payments to patent holders are necessary.

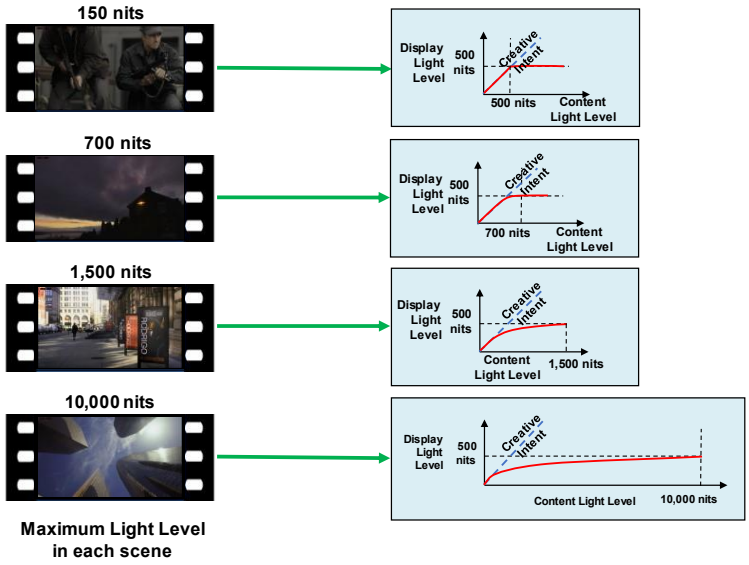
In a short period, HDR10 became widely utilized throughout the content, production, distribution and consumer electronics industries.

HDR10+: The next step in the ecosystem

HDR10 is what engineers call a "static metadata" system. Like all such systems, it utilizes one-size-fits-all "tone mapping" for the entire program, which limits flexibility. (A detailed discussion on metadata and tone mapping appears in the section "A closer look at HDR10+ technology.") For greater flexibility, a "dynamic metadata" system called HDR10+ was announced in April 2017. This direct extension of HDR10 is both backward and forward compatible and is seamless to implement. By using dynamic metadata, HDR10+ enables consumer devices to optimize tone mapping on a scene-by-scene and frame-by-frame basis.



Maximum light levels vary from scene to scene. For example, highlights in the skyscraper scene at the bottom could extend up to 10,000 nits. Static metadata can only generate a single tone mapping curve based on the maximum light level in the entire program.



In contrast, dynamic metadata indicates the maximum light level for each scene, enabling the display to optimize the tone mapping curve on a scene-by-scene basis. You get a closer match to the creative intent line in low-light scenes, delivering much more detail in the shadows.

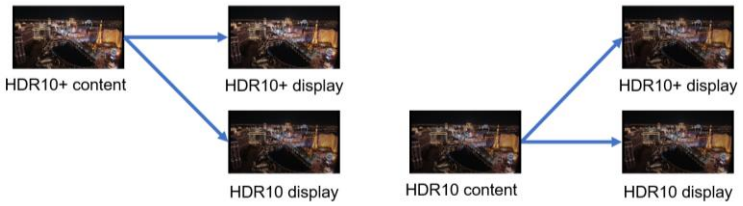
To deliver all these technical benefits as a consistent user experience, HDR10+ Technologies, LLC was created. Since June 2018, the organization has been supporting HDR10+ compatible content and services, plus certifying nearly 20,000 devices, which can then display the HDR10+ logo. This also helps promote consumer awareness.

The growing acceptance of HDR10+

From an industry perspective, HDR10+ provides powerful advantages in everything from professional content creation to consumer electronics.

1. **Simple program production.** Content creators can focus on making the best HDR content, knowing that HDR10+ consumer devices will provide optimum performance. HDR10+ mastering is straightforward and is supported by a choice of production tools which also make it simple to upgrade previously-produced HDR10 content to HDR10+.

2. **Total system compatibility.** HDR10+ content works seamlessly with both HDR10 and HDR10+ devices. This content will display on HDR10 devices, which simply ignore the dynamic metadata. HDR10 content also plays as intended on HDR10+ devices.



At left, HDR10+ displays realize the full benefit of HDR10+ content, which also works seamlessly on HDR10 displays. At right, HDR10+ displays support HDR10 content as well.

3. **Ease of implementation.** Like HDR10, HDR10+ is an open standard, works with a range of video codecs, requires no licensing fees and provides device optimization to take full advantage of the brightness of each specific display technology.

4. **Robust standardization.** HDR10+ has been established as SMPTE standard ST 2094-40 and has been recognized by the Blu-ray Disc Association, Consumer Technology Association, Digital Video Broadcasting, Society of Cable Television Engineers, Web Application Video Ecosystem, and Airline Passenger Experience Association. Work continues on additional standards.

5. **Growing industry support.** Over 170 companies have already signed on as HDR10+ adopters.

    - **Movies and episodic television** from 20th Century Studios, CBS, IMAX, Lionsgate, Paramount Pictures, Universal, and Warner Brothers
    - **Streaming platforms** including Apple TV+, Disney+, Hulu, Netflix, Paramount +, Prime Video, and YouTube among others. According to B.A. Winston, Vice President of Technology, Prime Video, “All of Prime Video’s HDR-enabled content has HDR10+ capability and metadata.” Anaji Wheeler,

Lead HDR Engineer at YouTube, noted that "HDR10+ allows for scene-by-scene changes on YouTube content, vs the same treatment for the entire movie."

- **TV manufacturers** including Hisense, Panasonic, Samsung, Skyworth, TCL, TPVision, and Vizio. In total, brands supporting HDR10+ represent nearly 80% of TVs sold worldwide.[3]
- **Video projector manufacturers** including BenQ, Epson, JVCKENWOOD, Samsung, and Valerion
- **Computer monitors and gaming displays** from companies like Samsung.
- **Mobile device manufacturers** including Apple, Motorola Mobility, OnePlus, Oppo, RealMe, Samsung, Vivo and Xiaomi. Brands supporting HDR10+ represent over 75% of the global smartphone market.[4]
- **Streaming devices** including Apple TV, Chromecast, Fire Stick, Roku, and TiVo
- **Blu-ray Disc players** from Panasonic, Pioneer, and Samsung
- **A/V receivers** from Marantz and Onkyo
- **Inflight entertainment**. "Panasonic Avionics is certifying all new Astrova inflight entertainment displays for HDR10+," says Kent D. Craver, Head of Global Marketing, Communications & Events. "This high dynamic range video technology is royalty-free and will allow commercial airlines to maximize the capabilities of 4K OLED and provide a stunning visual experience for their passengers."
- **Automotive infotainment** including Ready Display systems from HARMAN
- **System on Chip (SoC) fabricators** including Amlogic, Broadcom, MediaTek, Qualcomm, and Realtek
- **Professional tools and production facilities** from companies like ATEME, Harmonic, and others

HDR10+ is implemented in the Astrova inflight entertainment system from Panasonic Avionics.

[3] Based on first quarter 2023 sales.
[4] Based on first quarter 2023 sales.

Live production with HDR10+

The success of HDR10+ is also driving efforts to bring this level of performance to sports television and other live events. The result has been approved by the Advanced Television Systems Committee (ATSC) as an option for NextGen TV broadcasting (ATSC 3.0 standard). The benefits are substantial:

- Superb picture quality
- Low cost
- Compatible with existing workflows

This is leading to increasing adoption. NBC 4 New York, part of NBCUniversal Local, is currently broadcasting in HDR10+.

Gray Television, which has launched NextGen TV service in 30 markets, is using HDR10+ to upconvert their programming on these stations to provide consumers with the best possible viewing experience. Gray has been focusing its efforts on getting HDR10+ on all of their Fox affiliates, including WVUE-TV in New Orleans, the flagship home of Super Bowl LIX.

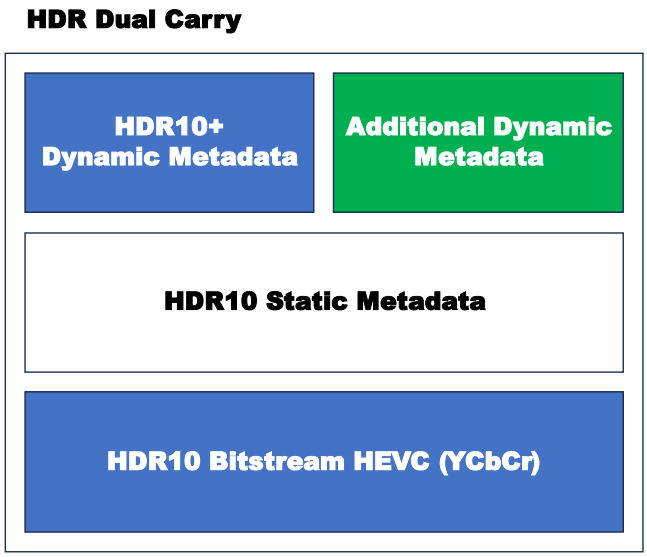
Supporting the broadcast workflow

Unlike movies and scripted television, where the creative team might spend weeks tweaking the color and grayscale, live production must all be performed in real time. Live broadcasts are the result of well-coordinated creative teams executing their workflows with split-second precision.

HDR10+ doesn’t interfere with these workflows. In particular, there’s no need for additional crew members to perform HDR10+ color shading. The only change is at the broadcast center, which only requires adding an encoder.

The simplicity of HDR10+ Dual Carry

A feature called “dual carry” enables broadcasters and other content distributors to offer multiple simultaneous HDR formats from a single stream. Not only does dual carry accommodate HDR10, HDR10+, and others, it’s also easy to implement. Dual carry simplifies processing, reduces storage, and delivers a superb experience for all HDR audiences.



A visible difference

The inclusion of HDR10+ metadata gives broadcasters an appealing, consistent HDR "look." Audiences get more exciting, more compelling content. As Thomas Burnichon, VP Innovation Strategy, at ATEME stated, "Introducing HDR10+ will make a difference for millions of viewers, enabling them to enjoy incredible colors that bring the events to life."

Shahar Bar, Senior Vice President, Video Products and Corporate Development at Harmonic stated: "Adding support for HDR10+ technology allows audiences to see every light, shadow and color flawlessly."

The HDR10+ Gaming experience

In their constant quest to increase the excitement and immersion of their worlds, game developers have wanted to enhance their content with HDR10+. The result was HDR10+ GAMING, announced in 2022. Here again, HDR10+ offers a range of powerful benefits:

- **Simple game development.** Thanks to cross compatibility, one game serves all displays.
- **A competitive edge**. In game play, HDR10+ means more than enhancing the white-knuckle gaming experience. Better grayscale gives players a competitive advantage. For example, players are better able to see competing race cars in a dark tunnel with intense backlight from a sunlit exit, or better able to see enemies obscured by fog or foliage.
- **No added lag.** Quick reaction times are key to game play. So players can't accept any technology that slows down video processing. Rendering HDR10+ content to the specific display performance introduces no additional lag.
- **Convenience.** There's no need for players to calibrate game settings according to on-screen test patterns. And the HDR10+ GAMING mode is automatic: enabled by compatible games, devices, and displays; otherwise defaulting to conventional playback.

The results have impressed the gaming community. Przemyslaw Czatrowski, Engineering Director at CD PROJEKT RED stated "Seeing *Night City* with HDR10+ turned on is a game changer. Utterly beautiful."

HDR10+ GAMING adoption

HDR10+ GAMING is now compatible with a growing range of PCs and mobile devices thanks to support from industry giants including Activision, Intel, Electronic Arts, MediaTek, and NVIDIA. In addition, many games are developed on commercially available gaming engines. One of the biggest is Unreal Engine, for which a plug-in supports HDR10+ GAMING.

Electronic Arts has released *Battlefield 6*; *F1 25*; and *Dragon Age: The Veilguard* with HDR10+ GAMING functionality, which delivers outstanding high dynamic range performance on compatible PCs and displays.

Nearly three dozen products powered by Intel integrated or discrete GPUs have also been certified by the HDR10+ Technologies LLC which will provide users with even more HDR gaming options.

Finally, Samsung Odyssey monitors are certified for HDR10+ GAMING and automatically adjust HDR settings to deliver a premium gaming experience with more accurate color, contrast and brightness.

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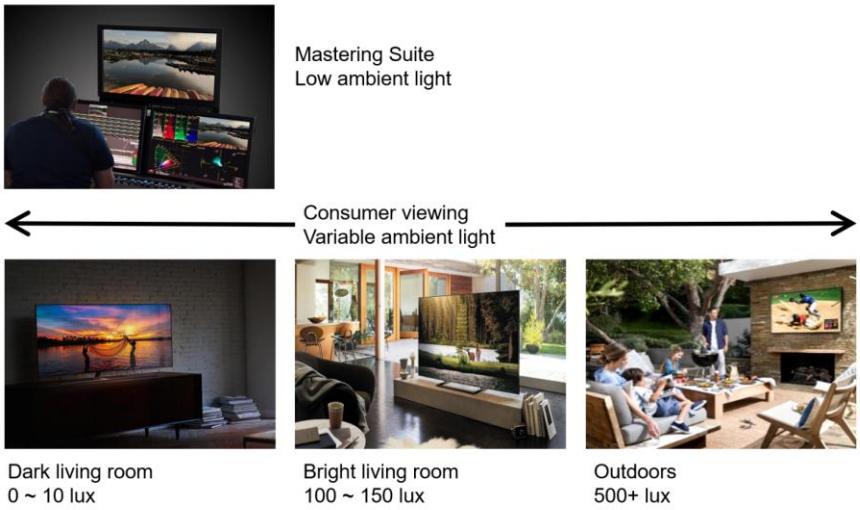
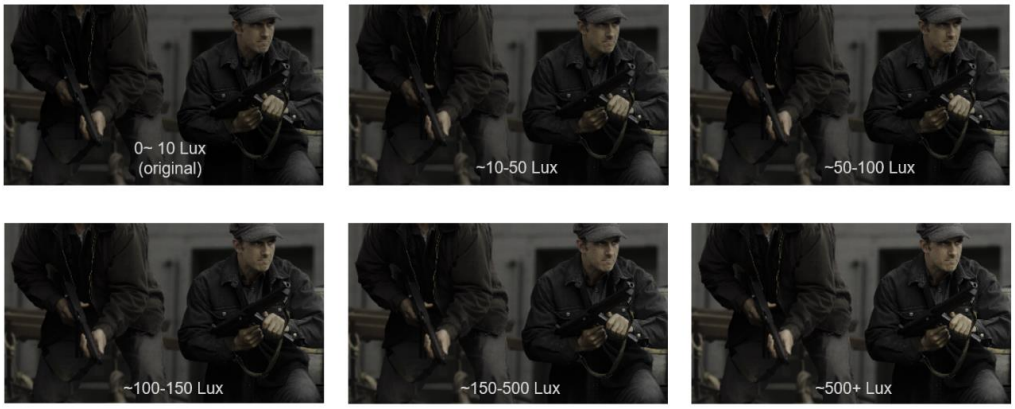
HDR10+ adaptive applications

Another critical consideration for HDR is the impact of ambient light on the viewing experience. Bright ambient light limits your ability to see shadow detail on the screen. For this reason, the mastering suites that content creators use for movies and TV programs purposely keep the ambient light low. Of course, in consumer viewing, ambient light varies greatly, depending on indoor or outdoor usage, time of day, window treatments, and number and intensity of room lights.



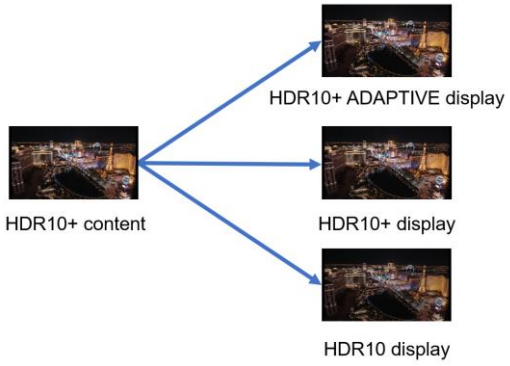
While mastering suites maintain low light (top), the ambient light levels in consumer viewing vary tremendously (bottom).

To address this, a new feature called HDR10+ ADAPTIVE delivers more consistent performance across a wide range of lighting conditions. The system takes advantage of light sensors built into the device and HDR10+ dynamic metadata to constantly adjust the presentation according to scene content and the amount of ambient light. For example, you get maximum adjustment for very dark scenes in very bright viewing environments: increasing brightness levels for better visibility. No adjustment is needed in very dark viewing environments.



When the ambient light is bright, HDR10+ ADAPTIVE provides precisely calibrated brightness enhancement of dark scenes. Image courtesy of Prime Video.

HDR10+ ADAPTIVE devices achieve optimal performance in every viewing environment. HDR10+ ADAPTIVE also works hand-in-hand with emerging features like Filmmaker Mode, which enables compatible devices to show movies and television programs the way their creators meant them to be seen. Best of all, content creators don't need to produce a separate HDR10+ ADAPTIVE version. In fact, a single HDR10+ program can realize the optimum performance each consumer device can deliver.

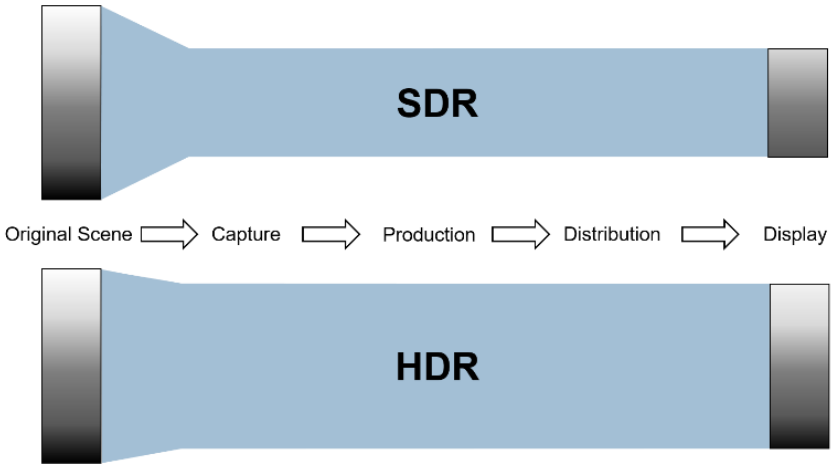


A single HDR10+ program serves all the displays in the HDR10 ecosystem.

Additional HDR10+ enhancements are being developed for in-car infotainment and other future applications. Stay tuned for further announcements.

A closer look at HDR10+ technology

Visual arts have long attempted to depict an original scene as in real life: first in painting and drawing, then photography and cinematography. Until recently, these efforts have always been constrained by relatively limited dynamic range: the difference in a reproduction system's brightness from the darkest possible black to the brightest possible white.



SDR (top) doesn't come close to the full range of brightness we can perceive in the original scene. HDR (bottom) does.

The human eye is capable of sensing light values from starlight to bright sunlight, a 10^{14} range of illuminance. In photographic terms, that's over 46 "f-stops" of dynamic range. But that total dynamic range is only achieved after many minutes of night vision adaptation. At any given moment, only a fraction of that range is available: estimated at around 13 to 16 stops.[5]

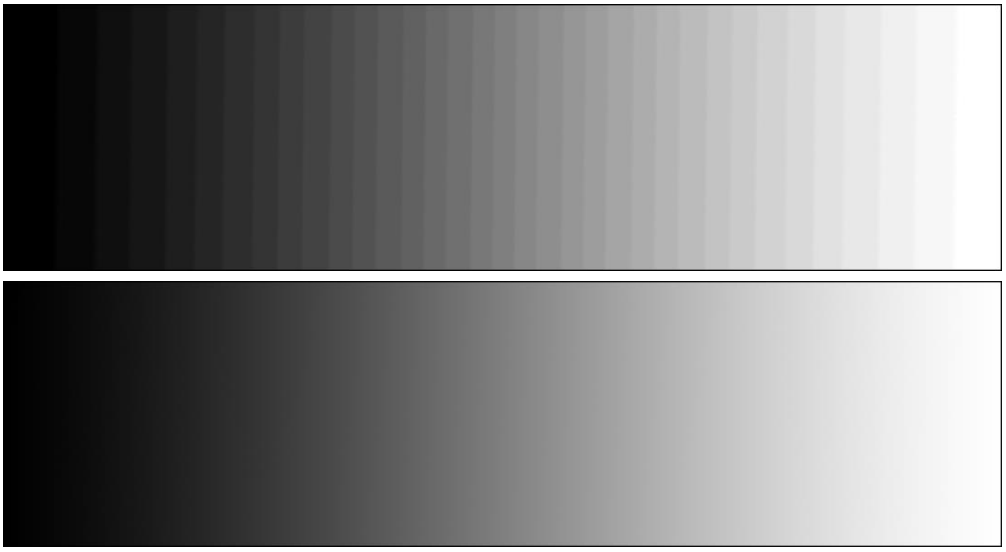
Based on the outmoded 1950s technology of Standard Dynamic Range (SDR), the original television imaging system could only capture, record, transmit and display less than 10 stops of dynamic range, limiting how content creators could convey scene brightness. Even the launch of HDTV in the 1990s did not change this.

A giant step forward, High Dynamic Range (HDR) takes advantage of the latest cameras, processing, storage, distribution platforms, and displays. It comes close to maintaining the full range of human vision from the original scene all the way through to the display. As a result, HDR opens up exciting new creative possibilities for directors, cinematographers and game developers, delivering a dramatically better, more engaging entertainment experience in movie theaters and on consumer televisions, projectors and even mobile devices.

[5] According to experts from the American Society of Cinematographers, Canon, Pro Video Coalition and Sony.

Grayscale quantization

Digital video systems use quantizing to encode grayscale. However, insufficient quantizing can mar the image by adding “banding” artifacts that can be noticeable on still images and particularly annoying on motion pictures. Designing a system with more quantizing bits can overcome this issue. Conventional high definition formats use 8-bit quantizing, which is adequate for SDR but insufficient for HDR. By going up to 16 bits, Ultra HD content and devices can support supple HDR grayscale rendition.



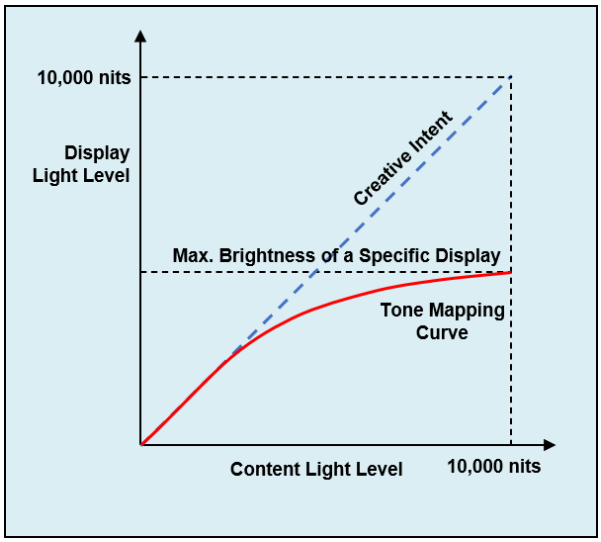
At the top, the distracting stripes of tone constitute “banding.” At the bottom, superior grayscale enables a smooth transition from dark to light.

Perceptual Quantization

Encouraged by research and development in several industries, the ITU created a significant standard for HDR encoding, called ITU R-BT.2100.

This includes a grayscale technique called Perceptual Quantization (PQ) which goes much further by using the grayscale levels more efficiently. Unlike the encoding used in SDR, PQ concentrates the grayscale levels where your vision is most sensitive. With PQ, High Dynamic Range provides not only more digital bits, but also the most efficient use of each bit.

Each PQ grayscale level corresponds to a specific display light level, from 0 to 10,000 nits. The internal processing of each consumer display adjusts the highest PQ levels to fit within the display’s brightness capability. This adjustment is called “tone mapping.”



The complete range of PQ content light levels extends to 10,000 nits. . Because no consumer display can achieve the full 10,000 nits, the internal processing of each display adjusts the highest PQ levels to fit within the display's maximum brightness capability. This adjustment, called tone mapping, gives you the full benefit of the display's brightest light levels, while maintaining detail in the highlights.

HDR10 static metadata

HDR10 also includes a standards-based feature known as "static metadata." Metadata is simply any relevant information about the primary video and audio content. For example, when you mail a letter, the address and the return address are metadata while the letter itself is the content. Static metadata simply means one unchanging set of data is used for the entire program.

This static metadata includes the following:

- Color volume information
- Average light level of the brightest frame in the program
- Maximum light level of the brightest pixel in the program

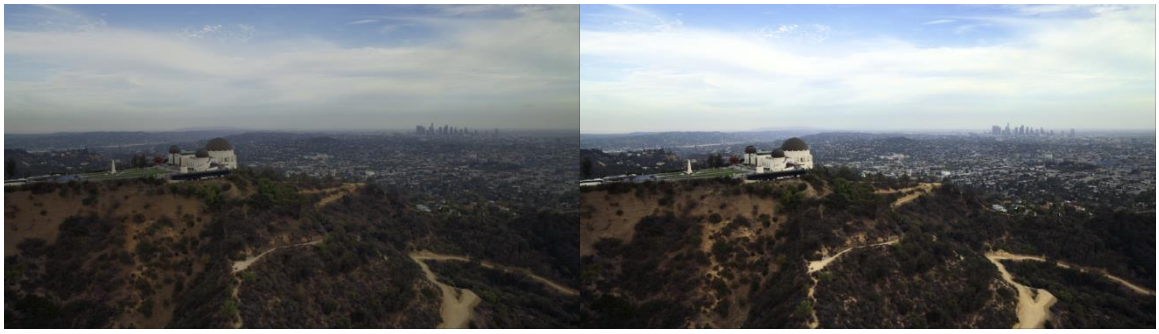
Since different display technologies have different brightness capabilities, the static metadata gives each device the information it needs to retain maximum detail in the highlights while taking full advantage of the display's specific brightness.

HDR10+ dynamic metadata benefits

Building upon the foundation of static metadata, HDR10+ adds the benefits of scene-by-scene "dynamic metadata." And unlike other such systems, HDR10+ identifies the most important areas of each scene to improve the reproduction of those areas. There are three steps.

1. During HDR10+ mastering, the system gathers comprehensive “luminance distribution” statistics that describe all the grayscale levels of each scene. The metadata includes the exact number of pixels in nine different grayscale ranges.
2. The mastering system then uses this data to construct a highly sophisticated, customized tone mapping curve for each scene. This “guided curve” is also included in the metadata.
3. Each consumer device adjusts the tone mapping curve according to the specific brightness capability of the individual display.

As a result, HDR10+ does much more than deliver highlights optimized on a scene-by-scene basis. You also get better rendering of subtle shades in the most important areas of each scene, where image elements like skin tones reside.



On the left, tone mapping with static metadata. On the right, HDR10+ guided tone mapping with dynamic metadata. Image courtesy of Prime Video.

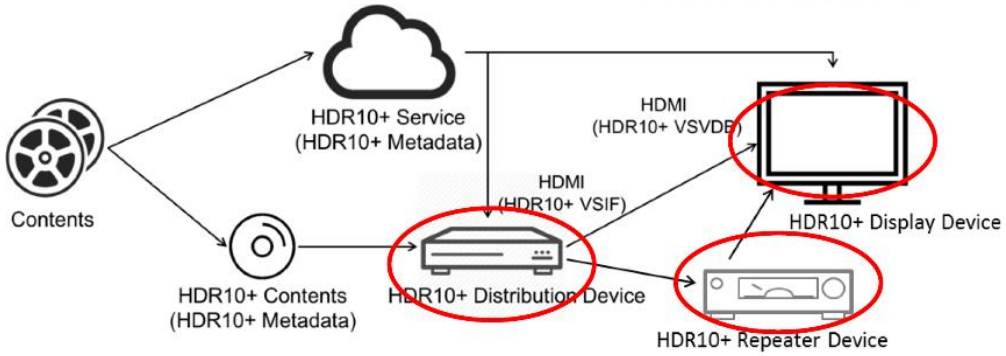
While each frame contains millions of pixels, all this dynamic metadata adds just a few hundred bits per frame, making the additional metadata easy to encode and distribute.

In addition, HDR10+ supports other improvements in picture quality.

- 8K resolution and beyond
- Quantization up to 16 bits
- Display brightness up to 10,000 nits

HDR10+ playback compliance

A substantial effort certifies that products identified with the HDR10+ logo are not only compatible, but also deliver the required picture quality. HDR10+ Technologies, LLC conducts a thorough device certification program. To qualify, televisions and mobile devices must pass over a dozen tests, offered at seven test centers around the world. This effort is supported by test equipment from Astro Design, Konica Minolta, Novanta Photo Research, Teledyne LeCroy, and Unigraf. Nearly 20,000 different devices have already been certified by this rigorous process and can carry the HDR10+ logo.



HDR10+ certification covers "distribution" devices like set top boxes and Blu-ray Disc players and "repeater" devices like AV receivers as well as "displays."

HDR10+ GAMING technologies

Compared to viewing movies and television shows, gaming imposes stringent demands on video systems. For this reason, HDR10+ GAMING offers several gaming-specific benefits:

- **Source Side Tone Mapping** for more accurate game output to compatible displays
- **Automated HDR calibration**, which automatically sets the display in a low latency reference mode
- **Support for variable refresh rates** for crisp action and maximum clarity

For more information, visit **hdr10plus.org**