

# 8K



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# 8K: THE NEXT LEVEL IN IMAGING

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# 8K IS HERE!

It seems almost impossible to comprehend that the next wave of video and display technology is already standing at the door, just a little over six years since the first 4K displays began shipping to market.

Numerous developments (seemingly disconnected) across the broadcast, display, and signal transport industries in this decade have combined to move 8K image capture, storage, transmission, and viewing from the theoretical to the practical, albeit at an initial price premium. Today, it is possible to purchase both large consumer televisions and desktop computer monitors with 8K (7680x4320) resolution, along with video cameras and storage for live 8K video production.

The national Japanese television network, NHK, has been producing and broadcasting 8K video content for almost a decade, providing coverage of every Olympic games since London in 2012. NHK has also led the way in development of 8K cameras, switchers, and format converters. Specifications for 8K signal capture and transport are now built into Society of Motion Picture and Television Engineers (SMPTE) standards.

Liquid-crystal display panel manufacturers in Asia are ramping up production of 8K “glass,” in search of profitability and anticipating a slow market shift away from 4K to 8K over the next decade. This, in turn, has created some headaches for transporting, switching, distributing, and interfacing these signals, due to their high clock and data rates.

In this paper, we’ll take a closer look at all of these developments and how they may impact the commercial audiovisual market in the not-too-distant future.

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# HOW DID WE GET HERE SO QUICKLY?

It's difficult to pinpoint a single factor driving the move to 8K, but a great deal of the momentum can be attributed to the display industry. Consider the timeline for 4K (Ultra HD) display technology, which only arrived in 2012 as a mainstream consumer and commercial product, initially as an 84-inch IPS LCD monitor with 4xHDMI 1.3 inputs and a hefty price tag exceeding \$20,000.

At that time, there were several overarching trends in display panel manufacturing. In Korea, the two largest display manufacturers (Samsung and LG Display) were building new “fabs” to produce larger LCD panels with Ultra HD (3840x2160) resolution. In addition, LG Display was accelerating production and shipments of large organic light-emitting diode (OLED) display panels, also with Ultra HD resolution.

In Taiwan and China, manufacturers including BOE, China Star Optoelectronics, and Innolux had also begun construction of larger fab lines to produce Ultra HD LCD panels, having decided that there was little to no profit in Full HD (1920x1080) LCD glass. In Japan, the sole remaining LCD panel manufacturers (Panasonic, Japan Display, and Sharp) were struggling with profitability and only Sharp had tried producing Ultra HD and 4K LCD panels at its then-world's largest Gen 10 fab in Sakai. (Sharp is now owned by Innolux parent Hon Hai Industries).



[FIGURE 1]

This 98-inch 8K LCD panel module is manufactured by CEC. (ROAM Consulting LLC)

Within a few years, the cost of Ultra HD LCD panels had plummeted to well below \$1,000, leading Chinese and Taiwanese manufacturers to investigate the feasibility of switching lines over to produce 8K panels with an eye toward maintaining future profitability. By late 2016, it was evident that the worldwide television market was shifting away from Full HD to Ultra HD models as profitability in TV sales continued to drop – even with new Ultra HDTV models. Why not move up in resolution?

Sharp had been showing an 85-inch 8K monitor prototype for several years at CES, IFA, and display shows. Now Samsung, LG, Innolux, CEC, and other brands were joining them with prototypes as large as 108 inches. The race was on! Today, manufacturers of Ultra HD televisions and display monitors face the same aggressive pricing challenges of two years ago. Caught between low wholesale panel prices and large investments in display fabs, the only logical move is up – to 8K resolution, and presumably improved profits.

As this paper is being written, it is now possible to buy an 85-inch 8K LCD television with high dynamic range for about \$20,000. At least one computer manufacturer now offers an 8K desktop monitor, and the first 8K OLED television is expected to begin shipments in early 2019.

Display manufacturers are determined to capture 8K market share as demand grows: Research firm IHS Markit predicts that nearly 430,000 8K televisions will ship worldwide by the end of 2019, a number that will grow to 1.9 million units by the end of 2020 and 5.4 million units in 2022.



[FIGURE 2]

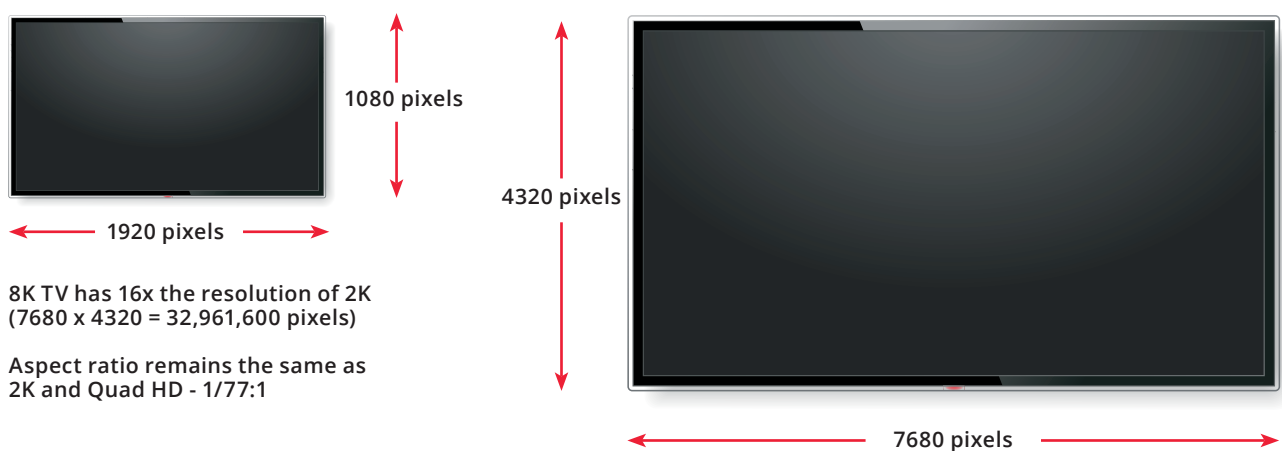
LG will start shipping an 88-inch 8K OLED TV for the high-end consumer market in 2019. (LG Electronics)

It should be noted that, according to IHS Markit, as much as 70% of the demand for 8K televisions will ultimately come from China with 15% additional demand in North America and 7% in western Europe. Given the interchangeability of display panels between consumer televisions and commercial displays, we can expect to see similar growth in demand for 8K imaging in the AV space with a lag of about two to three years behind the consumer marketplace.

# 8K DEFINITIONS AND SPECIFICATIONS

As with any new display technology, the marketing hype often gets out ahead of the facts. Catchall terms like “4K” must be further parsed to differentiate between the consumer Ultra HDTV format (3840x2160) and the cinema 4K format (4096x2160).

Similarly, there are two definitions for “8K” - a television display with 7680 horizontal pixels and 4320 vertical pixels in an aspect ratio of 16:9 (1.77:1), or a cinema format with 8192 horizontal pixels and 4320 vertical pixels (1.89:1). 8K displays have sixteen times the resolution of Full HD and four times the resolution of Ultra HD displays. (The 8K cine format also has sixteen times the resolution of a 2K video frame and four times that of a 4K video frame.)



[FIGURE 3]

A Full HD and 8K (UHD-2) display compared in resolution.

The Ultra HD and 8K television formats are designated by SMPTE as UHD-1 and UHD-2, respectively. SMPTE standard ST 2036-1 defines several versions of UHD-1 and UHD-2 displays, all based on the ITU Recommendation BT.2020 document that also defines high dynamic range (HDR) and a wider color gamut (WCG). Both features are intrinsic to 8K video and displays.

Nine different picture refresh rates are defined in UHD-2 for 8K video. Those are 23.98, 24, 25, 29.97, 30, 50, 59.94, 60, and 120 Hz. All can be used for 8K video capture and production, but only a few are supported in displays (24 Hz segmented frame, 25 Hz segmented frame, 30 Hz, 50 Hz, and 60 Hz currently, with 120 Hz frame rate support to come).

It should be noted that the only color space defined for UHD-2 is the Rec.BT2020 space with 10-bit color. Unlike early implementations of 4K and Ultra HD, high dynamic range and the BT.2020 gamut have been part of the UHD-2 specification from the start. This means that data rates for 8K signals will be correspondingly higher to accommodate the 10-bit and 12-bit luma and color values.

SYSTEM CATEGORY	SYSTEM NOMENCLATURE	LUMA OR RGB SAMPLES PER LINE	LINES PER FRAME	FRAME RATE (HZ)
UHDTV2	7680 x 4320/23.98/P	7680	4320	24/1.001
UHDTV2	7680 x 4320/24/P	7680	4320	24
UHDTV2	7680 x 4320/25/P	7680	4320	25
UHDTV2	7680 x 4320/29.97/P	7680	4320	30/1.001
UHDTV2	7680 x 4320/30/P	7680	4320	30
UHDTV2	7680 x 4320/50/P	7680	4320	50
UHDTV2	7680 x 4320/59.94/P	7680	4320	60/1.001
UHDTV2	7680 x 4320/60/P	7680	4320	60
UHDTV2	7680 x 4320/120/P	7680	4320	120

[TABLE 1] – The SMPTE ST-2036 definitions for different UHD-2 video frame rates are shown.

# TRANSPORTING AND INTERFACING 8K SIGNALS

As you might imagine, clock and data rates for 8K signals are quite a bit higher than those for Ultra HD signals. Whereas the CTA.861 specification for Ultra HD defines clock rates of 297 and 594 MHz for 30 Hz and 60 Hz refresh, the corresponding 8K / UHD-2 rates will be 4x multiples of those numbers.

Assuming a total frame size with CTA blanking of 8800 horizontal and 4500 vertical pixels, an 8K display signal refreshed at 30 Hz would have a pixel clock of 1,188 MHz (1.188 GHz). Refreshed at 60 Hz, the pixel clock will double to 2,376 MHz (2.376 GHz). And refreshing 8K video with a high frame rate (HFR) signal at 120 Hz doubles the pixel clock once again to 4,752 MHz (4.752 GHz).

On the display side, data rates for 8K signals can be as low as 17.82 Gb/s with 8-bit 4:2:0 color. Although 8-bit color is not in the UHD-2 specification, it is the only color bit depth low enough to pass an 8K signal through an HDMI v2.0 connection with either a 24 Hz or 30 Hz refresh rate, and is currently the only 8K mode supported by the first generation of 8K consumer televisions.

DISPLAY SIGNAL*	REFRESH (HZ)	COLOR MODE	BIT DEPTH	DATA RATE
7680x4320p	24	4:2:2	10-bit	19.1 Gb/s
7680x4320p	30	4:2:0	8-bit	17.8 Gb/s
7680x4320p	30	4:2:0	10-bit	21.4 Gb/s
7680x4320p	30	4:2:2	10-bit	28.5 Gb/s
7680x4320p	30	4:4:4	10-bit	42.8 Gb/s
7680x4320p	60	4:2:0	8-bit	35.6 Gb/s
7680x4320p	60	4:2:0	10-bit	42.8 Gb/s
7680x4320p	60	4:2:2	10-bit	57 Gb/s
7680x4320p	60	4:4:4	10-bit	85.5 Gb/s
7680x4320p	120	4:2:2	10-bit	114 Gb/s
7680x4320p	120	4:4:4	10-bit	171 Gb/s

[TABLE 2] – A comparison of different 8K/UHD-2 refresh rates and data rates.

(\* – Table assumes CTA standard blanking with total 8800x4500 pixels/frame)

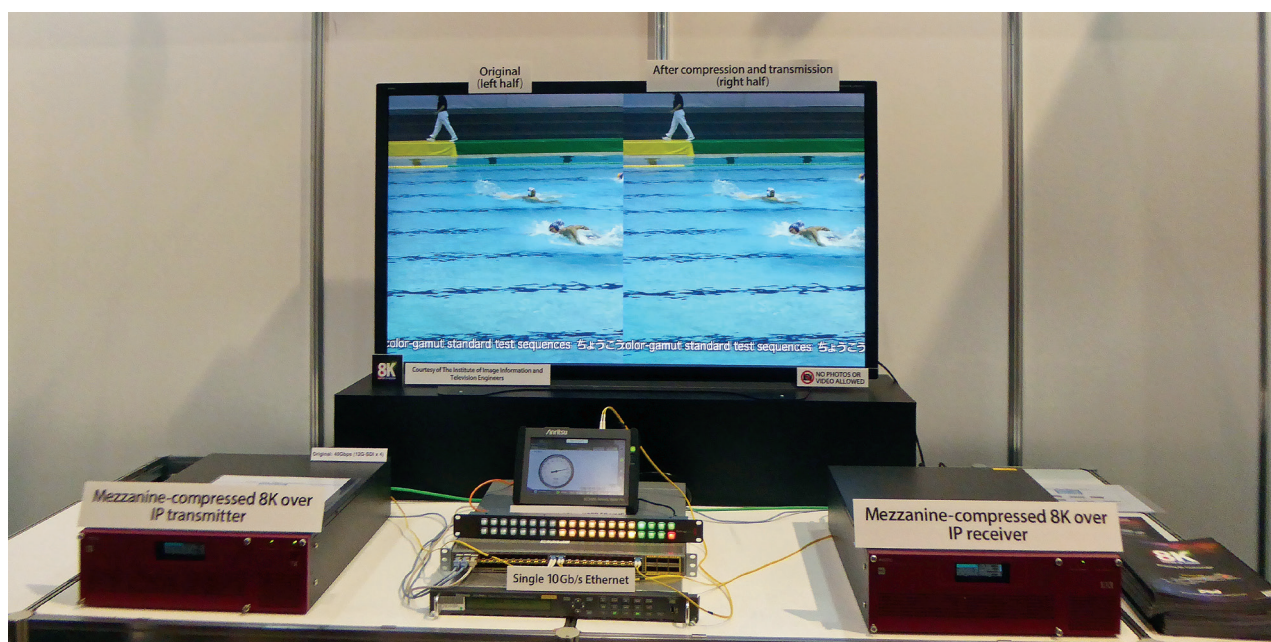


A more realistic data rate for 8K display signals would be 30 Hz with 10-bit 4:2:0 color, or 21.4 Gb/s. For 10-bit 4:2:2 color, that rate rises to 28.5 Gb/s, and for 10-bit 4:4:4, the resulting data rate becomes 42.8 Gb/s. Doubling the refresh rate to 60 Hz increases those rates to 42.8, 57, and 85.5 Gb/s, respectively. (HFR video would require uncompressed data rates exceeding 100 Gb/s!)

You can also see the challenges presented by 8K video when it is transported over a serial digital interface (SDI). At present, 3G SDI has a maximum data rate of 3 Gb/s, so a “quad” version (12G) and multiples of it must be used for transporting 4K signals. The same applies to 8K signals, which would require four “quad” SDI links to transport a 4320p/60 10-bit 4:2:0 signal.

Not surprisingly, new codecs have been proposed for compressing 8K video streams. The most promising of them is an adaptation of the Joint Photographic Experts Group (JPEG) codec, known as JPEG XS (a/k/a Tiny Codec, or TICO). JPEG XS is an entropy-based codec that has a visually lossless targeted compression ratio of 6:1, referred to in the industry as “mezzanine” JPEG compression.

TICO is a low-latency codec that does not introduce significant or noticeable image degradation with each encode/decode pass. Recent demonstrations at the NAB and IBC trade shows have been conducted with 8k/60 video at 6:1 compression with before/after comparisons on large 8K LCD monitors and no artifacts have been observed, even with high frame rate content.



[FIGURE 4]

NHK demonstrated 8K/60 4:2:0 video transport through a 10 Gb/s switch using JPEG XS at NAB 2018. (ROAM Consulting)



At NAB 2018, NHK showed 8K footage from the 2016 Olympic swimming competition, using JPEG XS to compress the source video by a ratio of 5:1 from approximately 48 Gb/s to 9.5 Gb/s. The intent of this demonstration was to show that 8K/60 10-bit 4:2:2 video can travel through a 10 Gb/s Ethernet switch and network for live production. (120 Hz HFR video would require a 100 Gb/s network and switch.)

At the display interface, it is likely that some form of Display Stream Compression will be required. This is also an entropy-based, low-latency codec that is compatible with both HDMI v2.1 and DisplayPort 1.3/1.4. With 2:1 maximum DSC, 8K/60 10-bit 4:2:2 video will easily pass through DP 1.3/1.4 and an 8K/60 10-bit 4:4:4 signal can be interfaced through HDMI 2.1. The adoption of 8K video may finally result in all parts of the signal chain, from camera to display, undergoing compression!

Although a discussion of 8K video file storage is beyond the scope of this paper, it's worth noting that one frame of 8K video (over 33 megapixels) ranges from 50 to 100 MB in size, depending on bit depth. That works out to 3 GB to 6 GB of storage for every second and 30 to 60 GB for every minute of 8K/60 video. A one-hour 8K video program could easily require 3.6 terabytes (TB) of storage.

# 8K DISPLAY TECHNOLOGIES

There are several different ways to reproduce 8K images. For direct viewing, the dominant technology is the liquid crystal displays (LCD), manufactured by numerous companies in Japan, Korea, and China. Both vertically-aligned (VA) and in-plane switching (IPS) LC layers are used with amorphous silicon (aSi) and indium gallium zinc oxide (IGZO) switching transistors. The latter are important because of both the size of the displays and the number of individual pixels in rows and columns that need to be rapidly switched on and off to avoid signal latency.



[FIGURE 5]

LG Display offers this 32-inch 8K LCD panel for high-end workstation monitors. (ROAM Consulting)

It was noted earlier in this paper that both high dynamic range (HDR) and wider color gamuts (WCG) are intrinsic parts of the ST-2036 UHD-2 specification. HDR can be achieved in LCDs with direct-view backlight illumination using newer, smaller LED arrays and improved color filters. It can also be accomplished with optical films containing quantum dots; small particles that emit intense, highly-saturated colored light when stimulated by blue LED photons.

The other direct-view technology suitable for 8K is a large RGBW OLED panel, currently manufactured by just one company (LG Display). Unlike LCDs, OLED displays are emissive, producing bright and saturated colors over wide viewing angles. OLEDs are also characterized by deep black levels and good low-level gray image detail. While OLED displays cannot produce peak (specular) white luminance levels as high as a quantum dot-equipped LCD, they can still create high dynamic range images with colors approaching the cinema DCI standard.

Another emerging direct-view technology is the inorganic RGB LED tile/wall. Recent developments have made it possible to construct individual LED tiles with a very fine pitch of .9mm. (Prototype LED tiles with .8mm pitch have also been exhibited.) These tiles can be combined into a large wall that would measure about 27.5 feet diagonally and offer a native resolution of 8K pixels. Such a wall would have the equivalent of a .15mm pixel pitch on a 55-inch 8K display.

A new class of LEDs known as MicroLED are now in development. These tiny LED emitters are bonded directly to a substrate and would allow 8K resolution with tiles having many times the pixel density of those currently used in fine-pitch LED walls. Researchers are also working on near-to-eye displays with 8K native resolution for virtual reality, although these semiconductor devices are a long way from market. (At present, there are no projection systems equipped with native 8K imaging devices.)



[FIGURE 6].

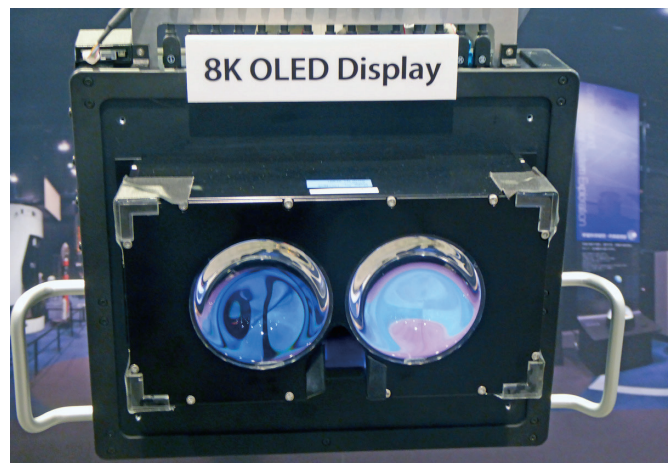
Samsung showed this 146-inch “wall” display at CES, using tiles of fine-pitch LEDs to achieve 8K resolution. (ROAM Consulting)

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# 8K IN PRACTICAL APPLICATIONS

You may be surprised to learn that 8K television broadcasts have been taking place since the turn of this decade in Japan. As noted at the start of this paper, NHK has done considerable pioneering work in the development of 8K cameras, 8K signal format converters, and 8K media storage products. They have also devised a method for broadcasting 8K images using two signals with different polarization in the UHF TV spectrum and have also led the way on implementing 120 Hz high frame rate (HFR) video.

In addition to covering all Olympic games since 2012 in 8K, NHK has also recorded and broadcast selected theatrical, operatic, and concert performances in this format, using custom-designed 8K/60 cameras. One recent innovation was the development of a small 8K camera sensor that was subsequently built into a 4.4-pound compact 8k camera, connected to a Steadicam rig for moving shots. At NAB 2018, NHK demonstrated a practical 8K slow-motion camera system for capturing fast action at 120 Hz, playing back at either 60 or 30 Hz.



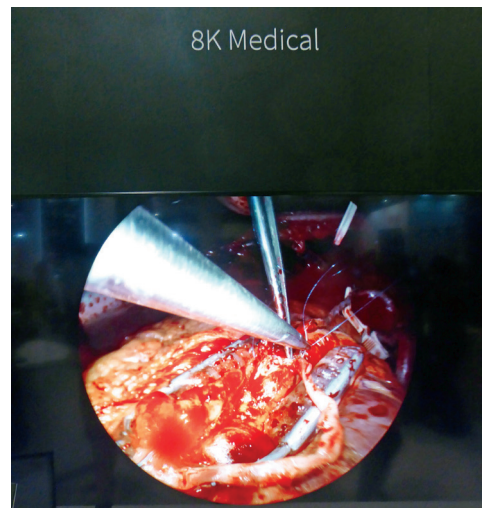
[FIGURE 7]

NHK slow-mo demo (left) and 8K OLED stereo display (right) at NAB 2018. (ROAM Consulting)

Both NHK and NTT (the Japanese national telecom company) have demonstrated high-efficiency codecs for 8K video, based on JPEG2000 and JPEG XS processing. The goal is to transmit 8K video over standard 10 Gb/s networks from source to viewer, decoding back to a high-speed display interface format for the “last mile” or streaming directly to an 8K TV with TICO decoding built-in.

Sharp has started shipping 8K video cameras with a selection of frame rates for both cinematic and video production. Their 8C-B60A camcorder uses a Super 35 sensor and can record up to 60 fps, 10-bit 4:2:2 video. At present, this camera is using lenses designed for 4K cameras (which are not all that abundant). At NAB 2018, Sharp also showed a scalable 8K storage system with a maximum capacity up to 1 petabyte across 108 3.5” SAS3/SATA2 drives.





[FIGURE 8]

Sharp is shipping an 8K video camera (left) and 8K medical imaging cameras and displays (right).

(ROAM Consulting)

In addition to obvious applications such as live sports and concerts, there is interest in using 8K video for arthroscopic surgery, heart surgery, and even eye surgery. Here is an application where fine detail, wide color gamuts, and high dynamic range all play an important part. Tiny tube cameras have been developed for non-invasive surgeries before, but this is the first time 8K imagers have been employed.

In the commercial AV space, there is strong interest in 8K imaging using either tiled 2K or 4K displays in wall arrays or single LCD and OLED panels. The advantage of tiling is the lower cost of tiles (LED or LCD) to get to 8K, but more complexity is introduced in signal distribution and processing. Single 8K displays have no mullions, but can be quite heavy and may require multiple signal input connections, depending on the display interface version. (Keep in mind that optical fiber is very much a practical solution for both interfacing and transport of 8K signals over networks.)



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# CONCLUSION

Make no mistake about it, 8K video has arrived. While we're far from a complete 8K acquisition, production, transmission, and display ecosystem right now, individual pieces of the puzzle are falling into place. Not surprisingly, 8K display technology has been first to market, followed by 8K cameras and sensors with storage, compression, and interfacing products bringing up the rear.

While it's still early to think about future-proofing AV systems to accommodate 8K, calculating the required data rates for 8K interfacing and signal transport is still a useful exercise as is taking the time to research and learn more about codecs suitable for transmission of 8K video. Don't procrastinate – technology moves from introduction to adoption very quickly!



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