

# 8K Overview

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# Outline

- Introduction
- Content Creation & Production
- Codecs
- Distribution
- Playback
- Displays

# Introduction

# The 8K Association

- Our Mission
  - Help educate consumers and professionals about 8K
  - Encourage the expansion of the 8K ecosystem
  - Aid consumers in 8K buying decisions via certification activities
  - Embrace all uses of 8K
  - [www.8kassociation.com](http://www.8kassociation.com); [www.discover8k.com](http://www.discover8k.com)



# 8KA Members

- TV Brands
  - Changhong
  - Hisense
  - Panasonic
  - Samsung Electronics
  - TCL
  - TPV (Philips)
- Panel Makers
  - AUO
  - BOE
  - CSOT
  - Innolux
  - Samsung Display
- Streaming Service Providers
  - Tencent America
  - Chili
- Technology or Equipment Providers
  - Allion Labs
  - Astro Design
  - Ateme
  - Intel
  - Main Concept
  - Universal Electronics
  - Xperi
- Chip Set providers
  - Mediatek
  - Novatek Microelectronics
- Content Creators
  - IMAX
  - More to be announced

# Major Activities

- Certify 8K TVs – 31 models so far
- New independent filmmakers campaign
- New industry documents coming
- Conferences, workshops, webinars
- Consumer campaign

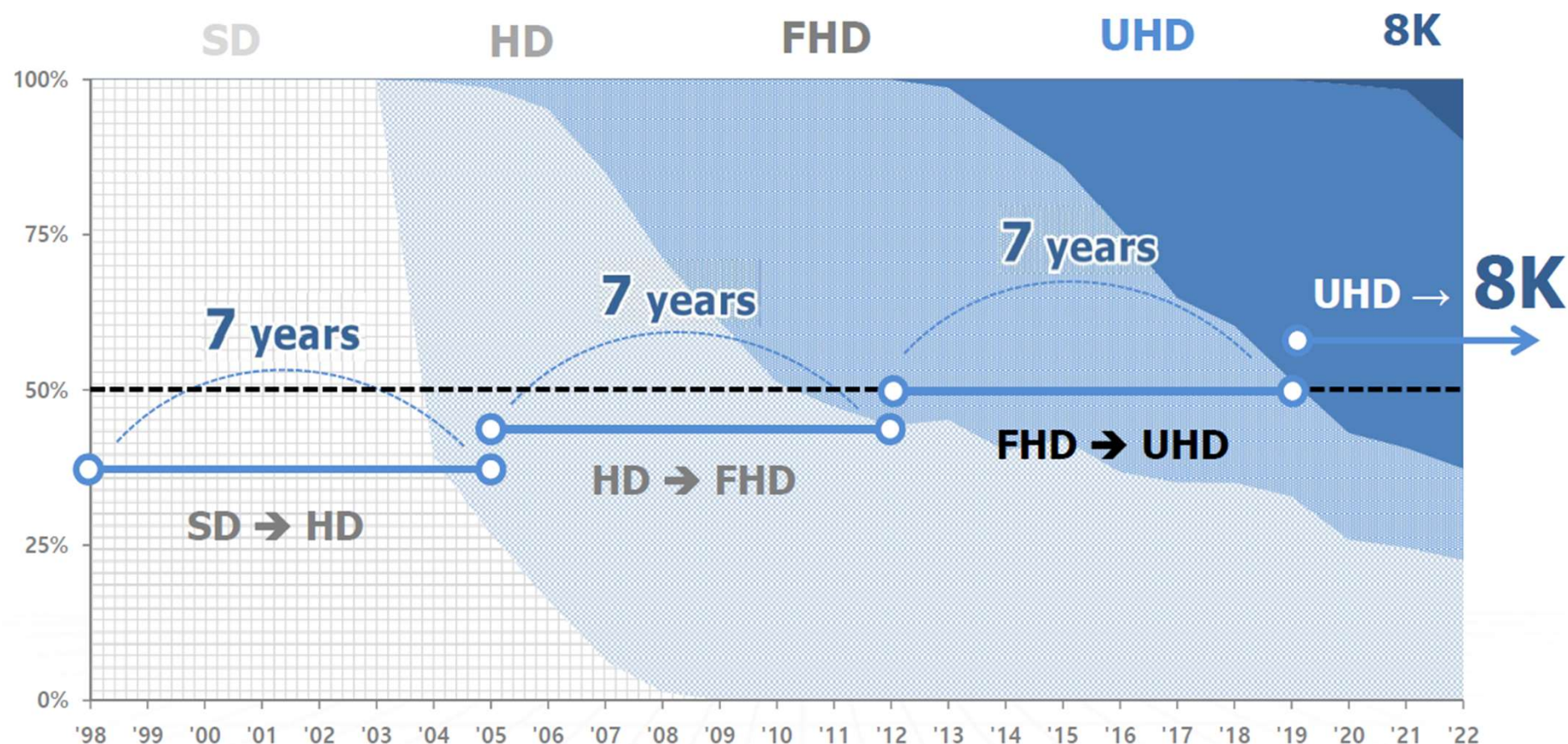
# What is 8K?

- ITU UHD-2 resolution: 7680 x 4320





# 8K is Right on Schedule



7 Year Cycle from Display Introduction to 50% of Sales  
(credit: Samsung Display)



# Why 8K?

- 8K is next stage in SD-to-HD-to-4K-to-8K trend
- 8K is more than just extra pixels
  - It includes HDR elements too - wide colors and extra dynamic range
- It is the highest quality capture and display level
- Creates a “looking thru the window” image
  - Can be almost 3D-like
- 8K capture adds flexibility and makes better 4K or 2K deliverables

# The State of Lens-to-Livingroom 8K

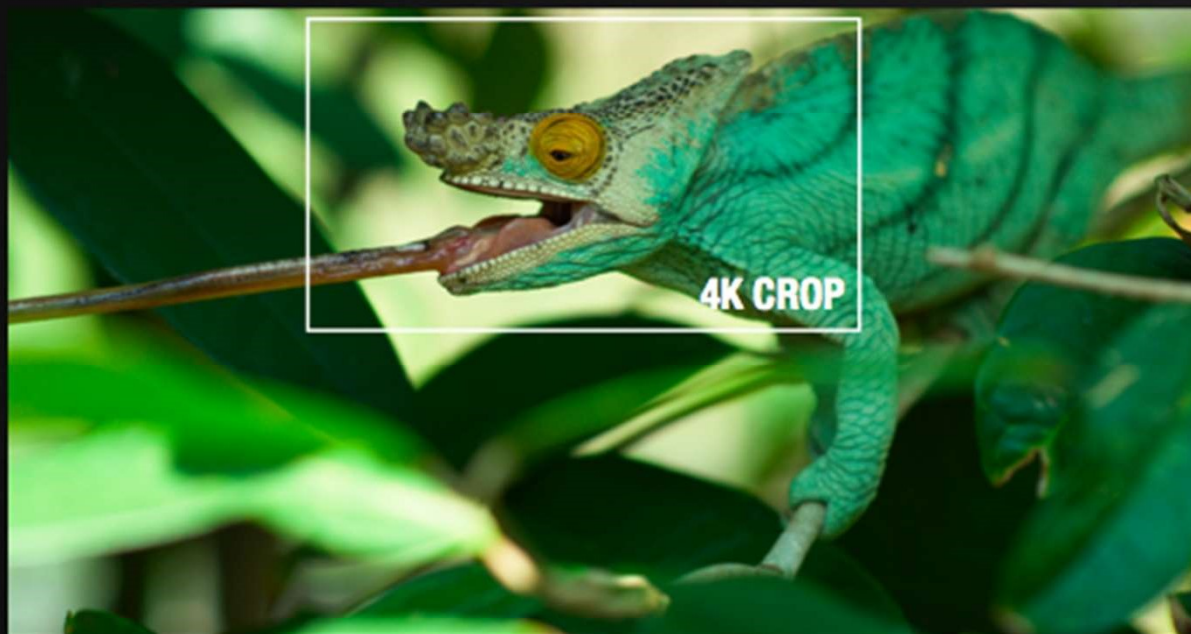
- 8K TVs from most major brands are available today
- All the production equipment for live and file based capture and production is here
- NHK has been broadcasting 8K to consumers since Dec. 2018
- YouTube and Vimeo have thousands of 8K clips
- Major sporting events have and will feature 8K
- 8K subscription services exist
- The ecosystem is developing like 4K 6-7 years ago

# 8K Content Creation & Production

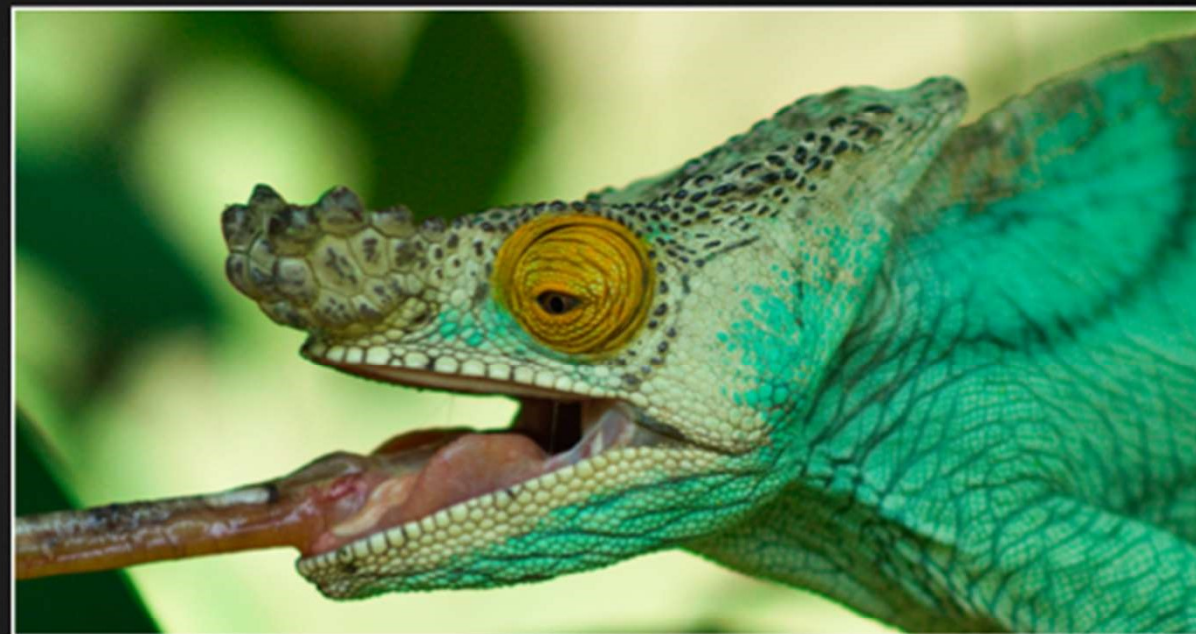
# 8K Capture Benefits – Live & File-based

- 8K enables wide FOV with high pixel density
  - can see entire sports field
- Enables 4K or 2K reframing or region-of-interest tracking
- Enables 2K/4K pan-and-scan
- Creates lower noise content
- Creates better 4K or 2K deliverables
- Video frame grabs suitable for still images for commercial use
- Improved special effects workflow
- Future-proofing

## RESOLUTION OPTIONS



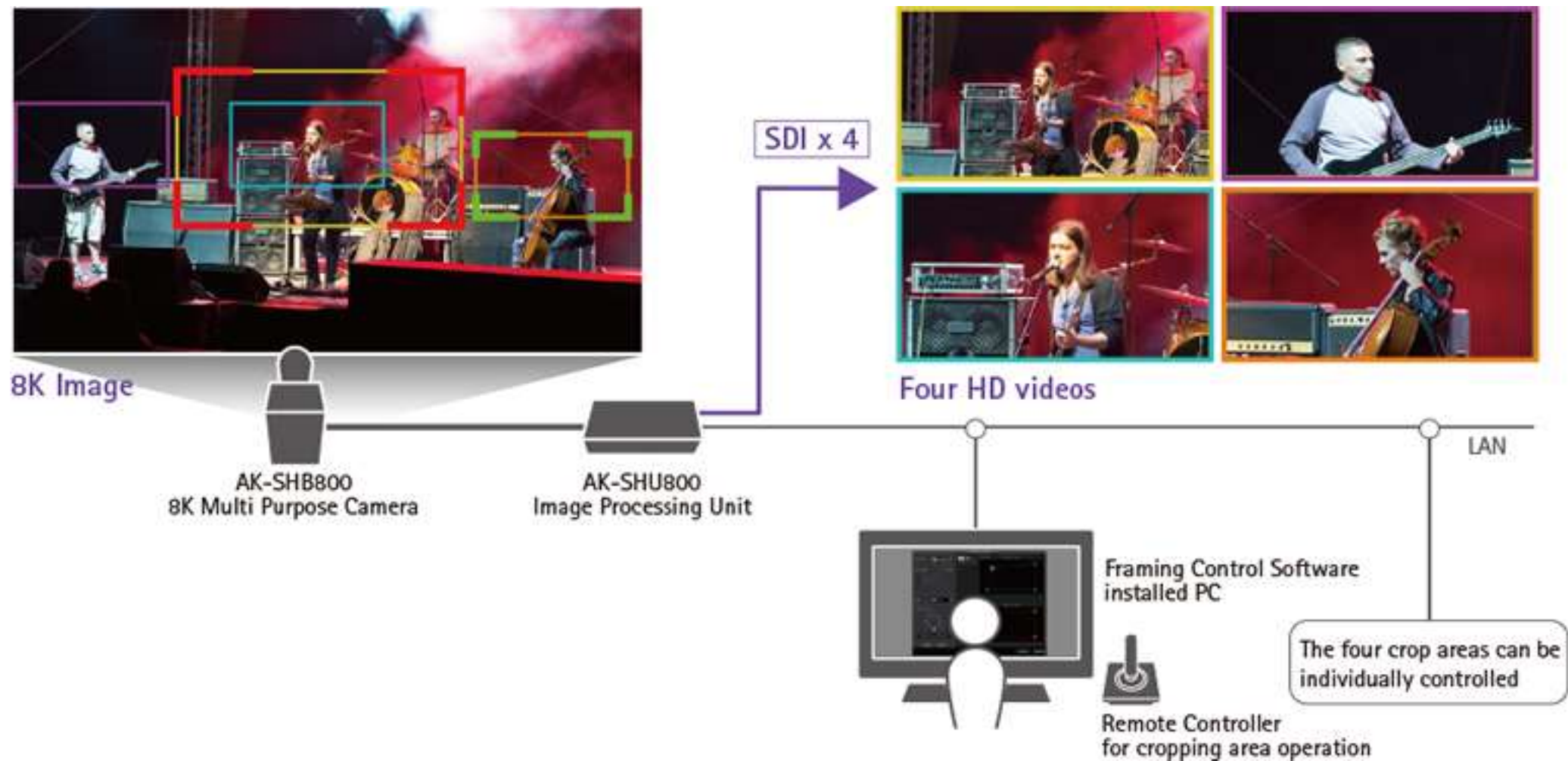
**8K IMAGE**



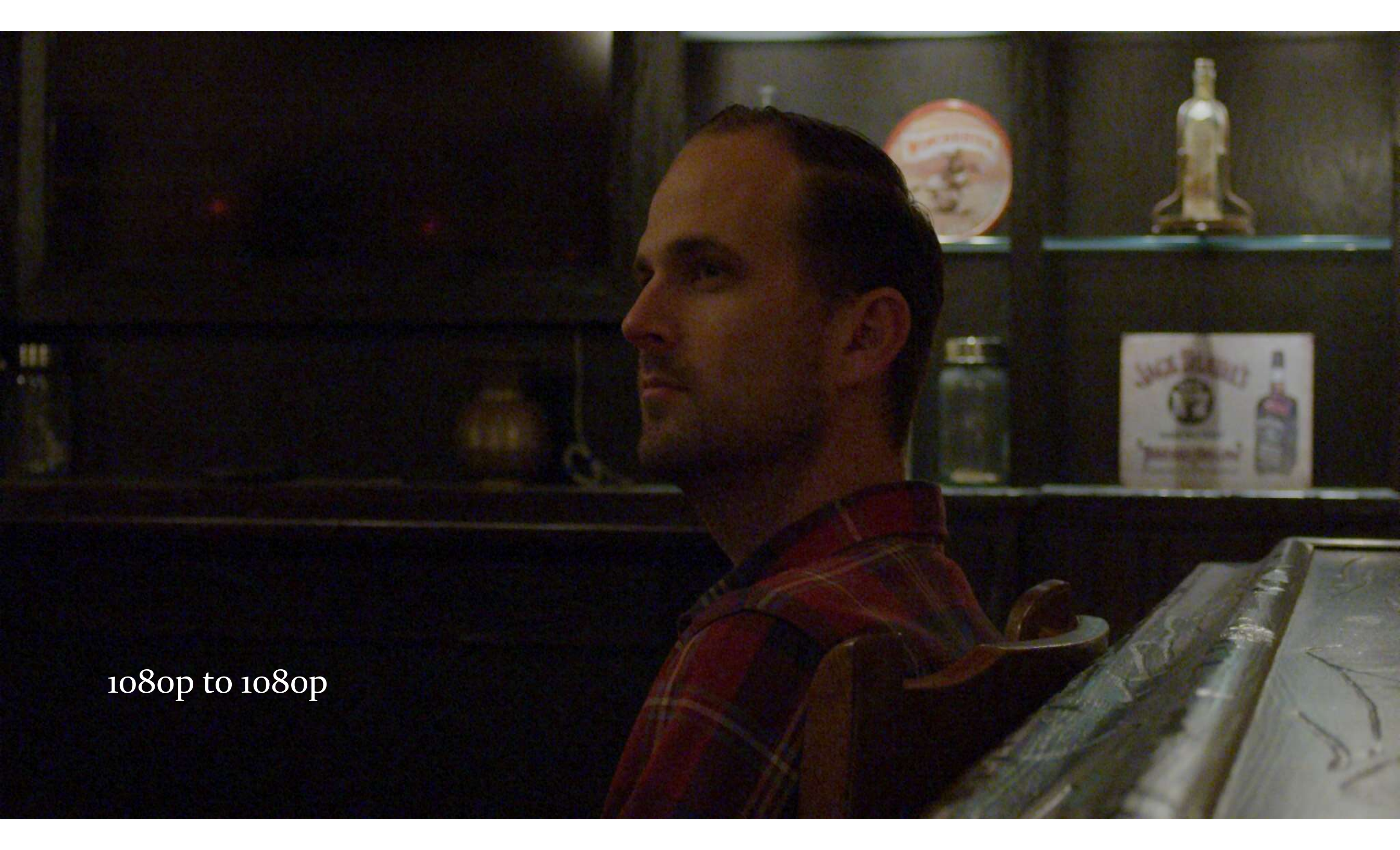
**4K CROP**



# Region of Interest

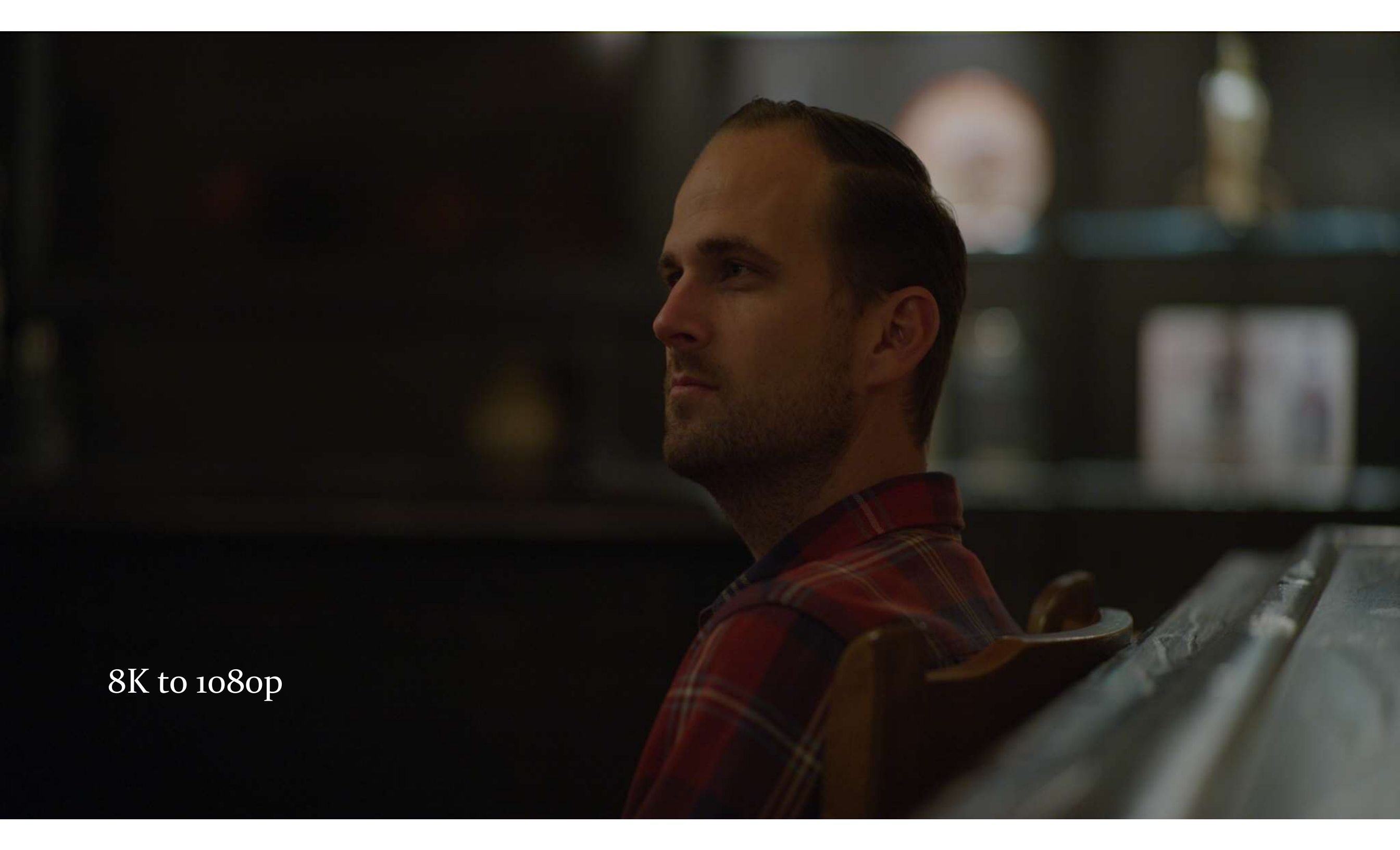






1080p to 1080p

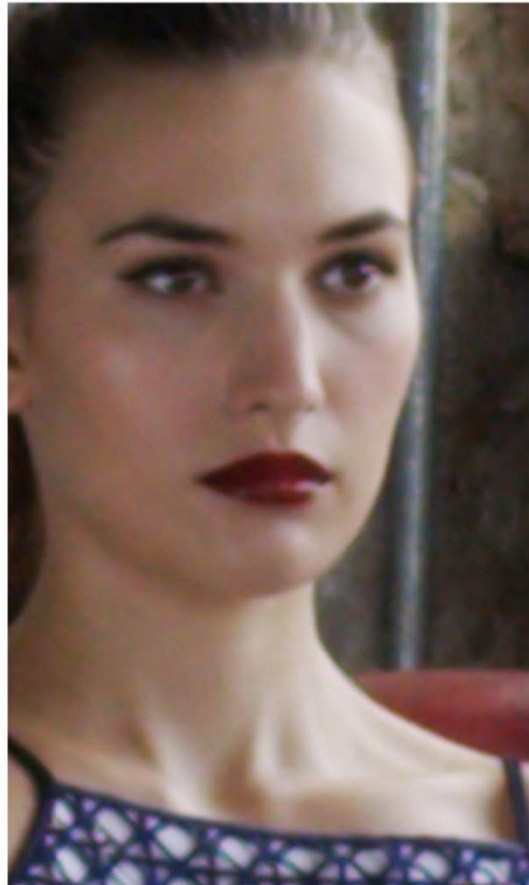




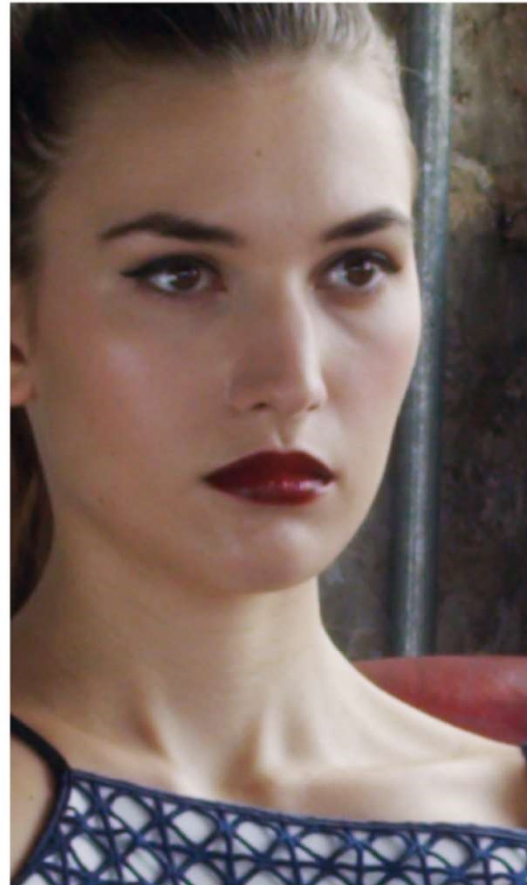
8K to 1080p

# RESAMPLING COMPARISON

4K Deliverable



2K



4K



8K

**RED**

# 8K Cameras are Here

- Cinema-grade 8K cameras available from RED, Panavision, Astrodesign, Sony, Z-Cam, Kinefinity
- Broadcast-grade cameras available from Sharp, Sony, Hitachi, Panasonic, Ikegami
- Consumer-grade cameras coming from Sharp, Bosma, Skyworth, Canon
  - 8K cameras in smartphones (Samsung, Sharp, Nubia, Sony)
  - 8K cameras will be major source of user generated content for YouTube, Social Media, and Influencers
- Lower cost cameras and lenses will driving market



# Sony - Broadcast

- **Sony UHC-8300**
- 3x 1.25" 8K CMOS imagers for 7680x4320 resolution
- 8K/4K/HD simultaneous output to support current 4K/HD workflow
- 8K 119.88p image scanning output over octal 12G-SDI
- S-Log3 and BT.2100 HLG with BT.2020 wide color space and HDR/SDR simultaneous SR Live operation
- Weight 7 kg (15 lbs 7oz)



Sony UHC-8300 8K Camera

# Sharp - Broadcast

- **Sharp** announced their 8C-B60A 8K camera in the fall of 2017
  - Uses a Super 35mm sensor with 33 MP
  - Frame rates from 23.98 to 60 Hz
  - HLG gamma curve standard
  - Uses Grass Valley HQX Codec (7680×4320 4:2:2 10-bit)
  - Video compression rate 6 Gbps (8K 60p: approx. 1/7 compression)
  - Recording capacity 40 minutes with 2 TB SDHC storage
  - ~\$80K



# RED - Cinema



RED 8K Cameras

- **RED Ranger Monstro 8K (~\$60K)**
  - 35.4 Megapixel CMOS Sensor (full frame)
  - 40.96 mm x 21.60 mm (Diag: 46.31 mm)
  - 60 fps at 8K Full Format (8192 × 4320)
  - 75 fps at 8K 2.4:1 (8192 × 3456)
- **Red Ranger Helium 8K (~\$35K)**
  - 35.4 Megapixel CMOS Sensor (35mm)
  - 29.90 mm x 15.77 mm (Diag: 33.80 mm)
  - 60 fps at 8K Full Format (8192 × 4320)
  - 75 fps at 8K 2.4:1 (8192 × 3456)

# Z-CAM - Cinema

- Z CAM E2-F8 (~\$6K plus lens)
  - Full-Frame 8K Cinema Camera
  - PL Mount
  - 8K/30
    - 10-bit 4:2:2 HEVC
    - 12-bit RAW
  - 14 f-stops
  - Cfast media recording at 300 Mbps
  - USB-C and Ethernet ports





# Canon - Consumer

- EOS R5
  - Full-frame sensor
  - 8K/30 or 4K/120 video
  - Dual pixel auto focus
  - In-body stabilization
  - Auto cloud uploads
  - 4:2:2 10 bit HEVC recording (Canon log or PQ)
  - Super hi-speed CFexpress cards or SD UHS-II cards
  - ~\$4K (w/o lens); ~\$5K with lens





# Sharp - Consumer

- **Sharp** 8K DSLR camera
- Micro Four Thirds 8K sensor
- Records 4320p/30 with H.265 encoding
- UHS-II SD card slot
- 5" flip-out display for viewing
- HDMI 2.0 port
- ~\$4K



# Samsung - Smartphone

- S20/S20+/S20 Ultra 5G
  - 8K/24 video but not HDR
  - 33Mp stills
- HEVC recording
- Export video to YouTube or cast to 8K TV
- ~\$1K



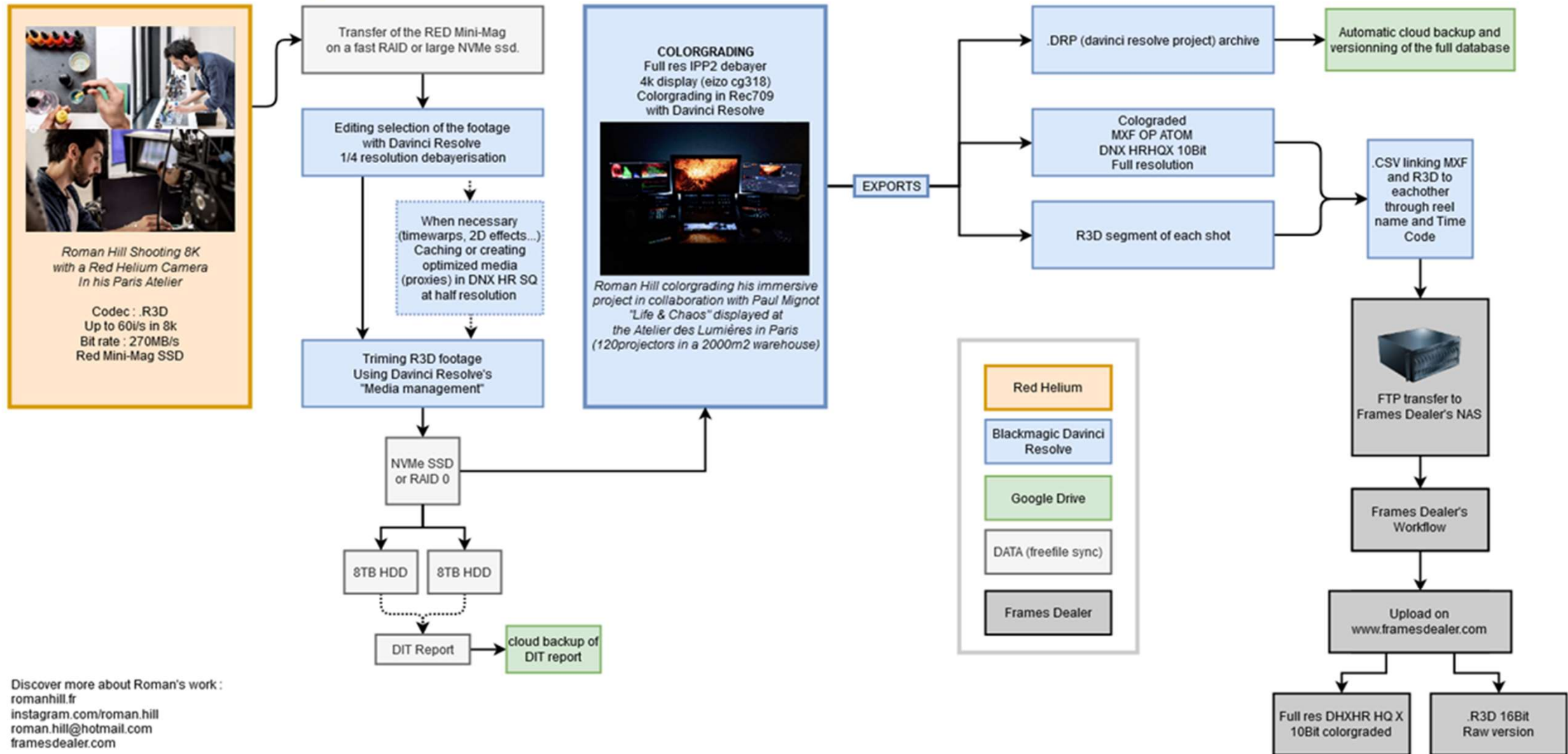
# 8K Production

- 8K live and off-line production workflows are here today
  - Finish in 8K, 4K or 2K
- Major editing and grading software now 8K capable
- CPU/GPU hardware is ready but high-end solutions needed
- Storage and infrastructure bandwidth needs upgrading
- Production needs similar to 4K needs 6-7 years ago
  - Options expanded and costs came down
  - 4K now mandatory deliverables for some

# 8K Production

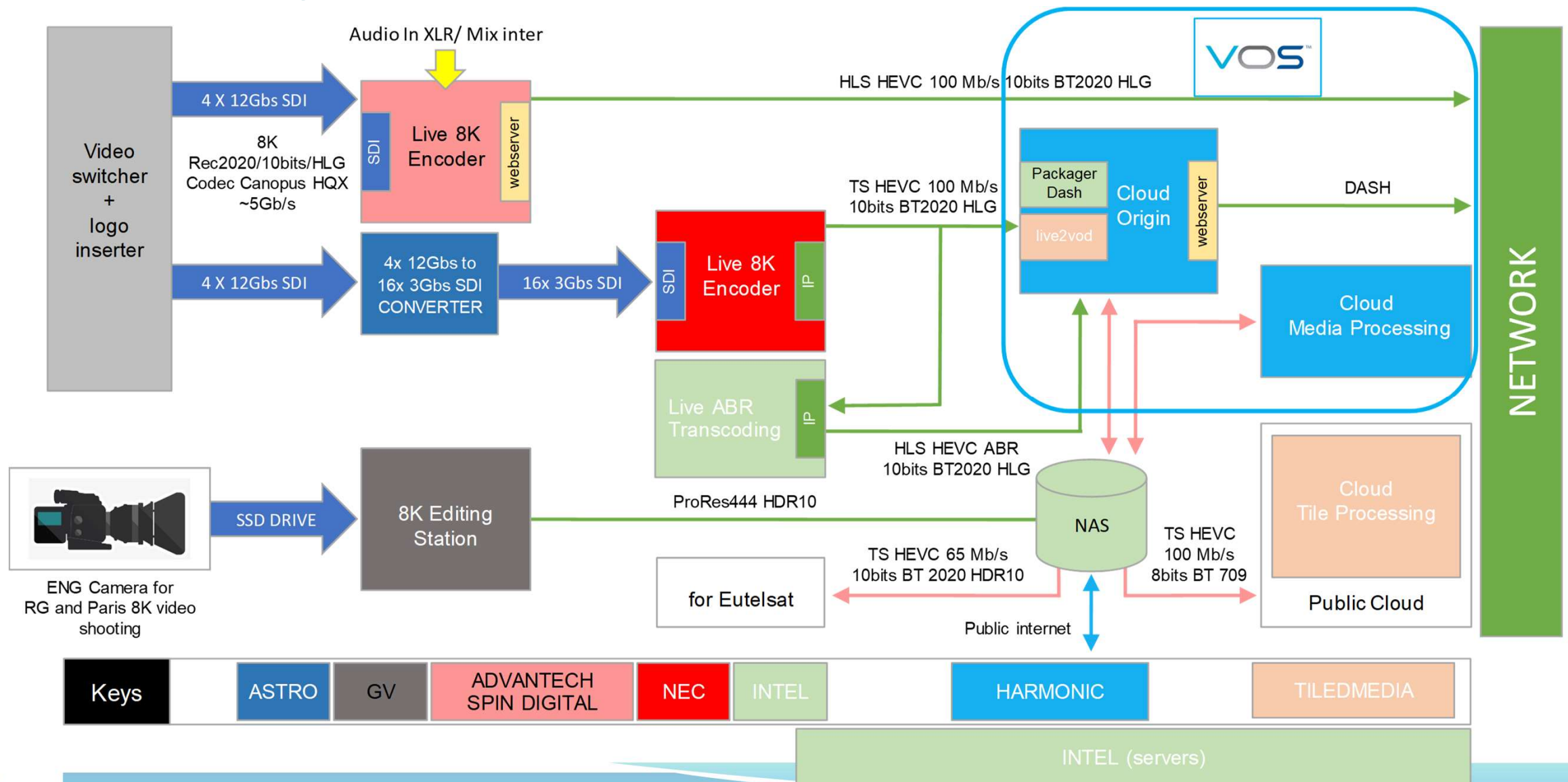
- 2020 Summer Olympics in Japan was to be captured and broadcast in 8K in Japan
  - Postponed a year
  - 2022 Beijing and 2024 Paris Olympics likely to be 8K as well
- Many trails/demos underway in other sports
- Some movies being captured in 8K
  - Film-based movies can be easily scanned in 8K
- Upconversion to 8K for mastering possible too

# Sample File-Based 8K Workflow





# Sample Live & VOD 8K Workflow



Source: Harmonic

# Deliverables

Encoder	Function	Target bitrate	Application
NEC	Live	TS 100Mbps	TV streaming
Advantech	Live	HLS < 100Mbps	TV streaming
Intel	Live	HLS < 100Mbps	TV streaming
Harmonic	File	DASH SBR HDR10 65Mbps	TV streaming
		DASH ABR 100Mbps	VOD to mobile
		TS 100Mbps	Tiling export
		TS 65Mbps	DTH export

Over 5G

To VR headset  
Over Satellite

# 8K Production Summary

- The entire 8K production and mastering chain for live and file-based workflows are available
  - More diversity and lower prices needed
  - Faster and cheaper storage and interfaces needed
- There are clear benefits for 8K capture and/or remastering
  - Not all understand these benefits yet

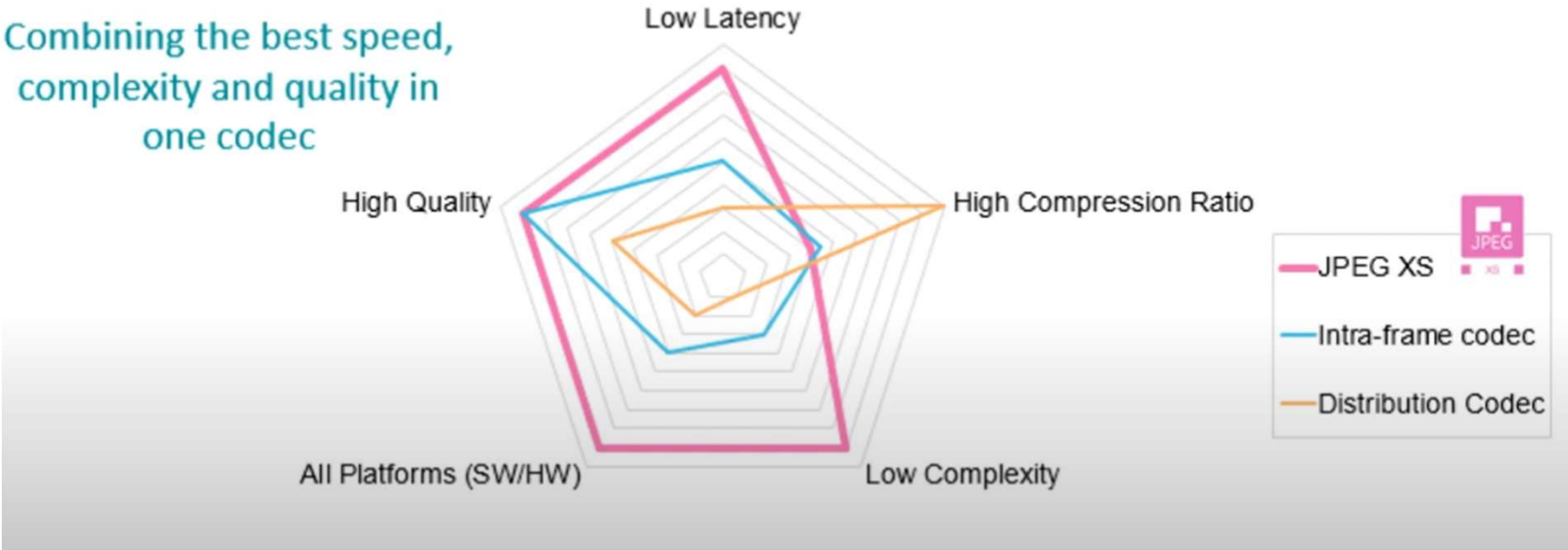
# Questions?

# Codecs



# Mezzanine Codec Prospects

FORMATS	TICO-XS (JPEG XS)	TICO (SMPTE RDD35)	IP NETWORKS & SDI MAPPING EXAMPLES
8K/60	2 Gbps – 6.4 Gbps	~8 Gbps	1 to 4 streams over 10 GbE (CAT 6) Single 3G/6G/12G-SDI
8K/120	4 Gbps – 12.8 Gbps		1 to 2 streams over 10 GbE (CAT 6) Single 6G/12G-SDI

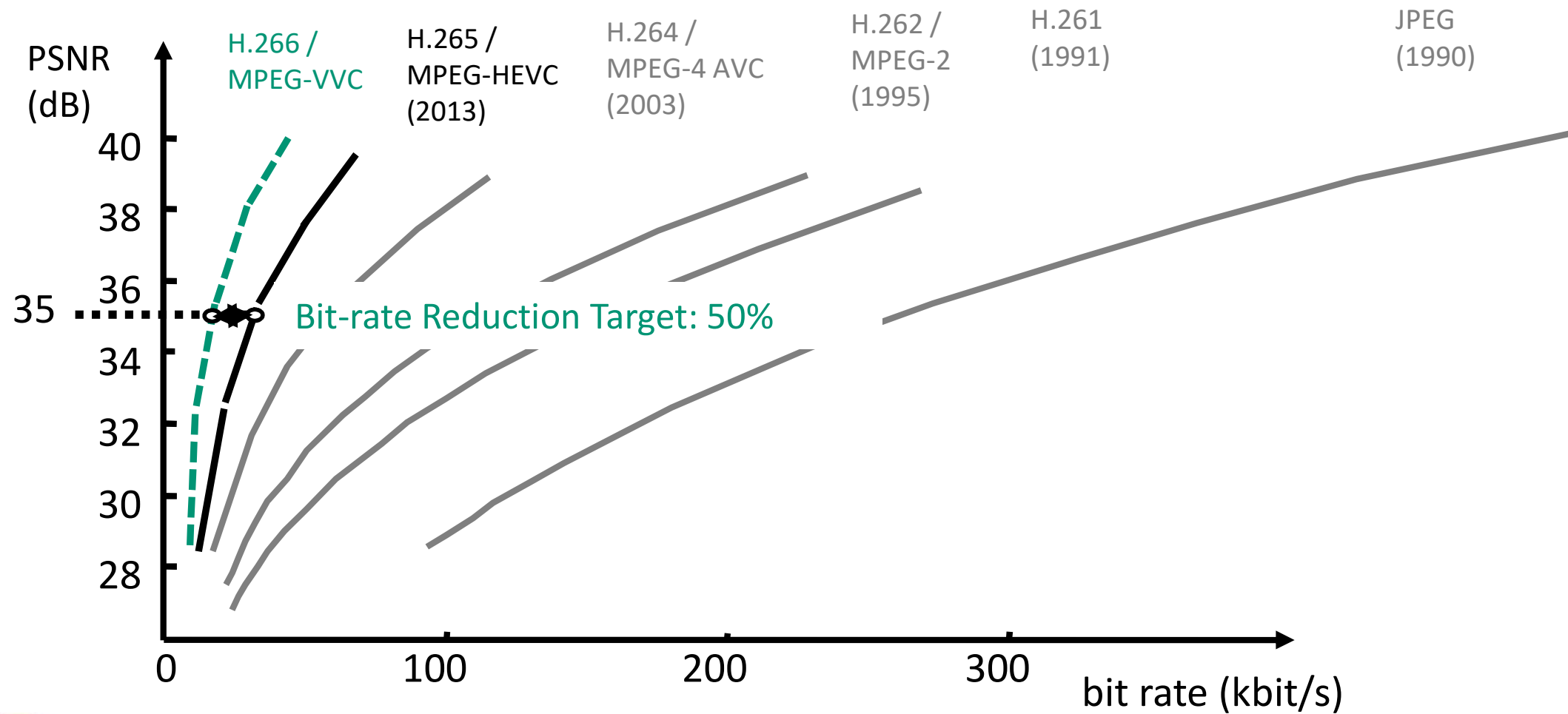


- Mezzanine codecs with high quality and low compression ratios needed for 8K production
  - JPEG-XS now standardized
- Visually lossless in 10:1 to 15:1 compression range
- High quality after many compress/decompress cycles
  - Similar to JPEG200 but less complex
  - Better than ProRes
- Fits SDI and IP-based infrastructure

# Distribution Codecs

- Unique time – many new codecs coming on line
  - HEVC
  - AV<sub>1</sub>
  - Versatile Video Codec (VVC)
  - Essential Video Coding (EVC or MPEG-5 Part 1)
  - Low Complexity Enhancement Video Coding (LCEVC or MPEG-5 Part2)
  - AVS<sub>3</sub> (AVS Industry Alliance)

# MPEG Codec History



# HEVC

- Developed by MPEG as replacement for AVC
- Achieving 40-50% bit rate reduction for same quality
- Increased encoding horsepower needed
- Increase decoding horsepower needed
- Not as widely used for 4K as expected
- Royalty-based with confusing IP pool = uncertainty

# AV1

- Being developed by Alliance for Open Media (AOM)
- Roughly based on VP-10 from Google
- Supposed to be royalty free
  - New IP claim from Sisvel
- Similar-to-heavier encoding/decoding efficiency and density vs. HEVC
- Being implemented on YouTube for all resolution ladders
- Major streaming service providers evaluating
- Need wide availability of hardware and software decoders for broad adoption



# EVC

- Being standardized by MPEG
- Being pushed forward by Samsung, Huawei, and Qualcomm
- Baseline profile uses older, royalty-free components
- Main profile better for 4K/8K – should have clear royalty licensing
- ~30% lower bit rates vs. HEVC

# VVC

- In development in MPEG
  - Larger blocks and massive parallelization by GOP segment will speed encoding
- Currently at 40% encoding efficiency improvement vs. HEVC
- Software encoders and decoders are set to be release in the autumn of 2020
- Hardware designs in process now
- Recent demo of 4K satellite distribution
- 2022 likely time frame for first commercial roll outs

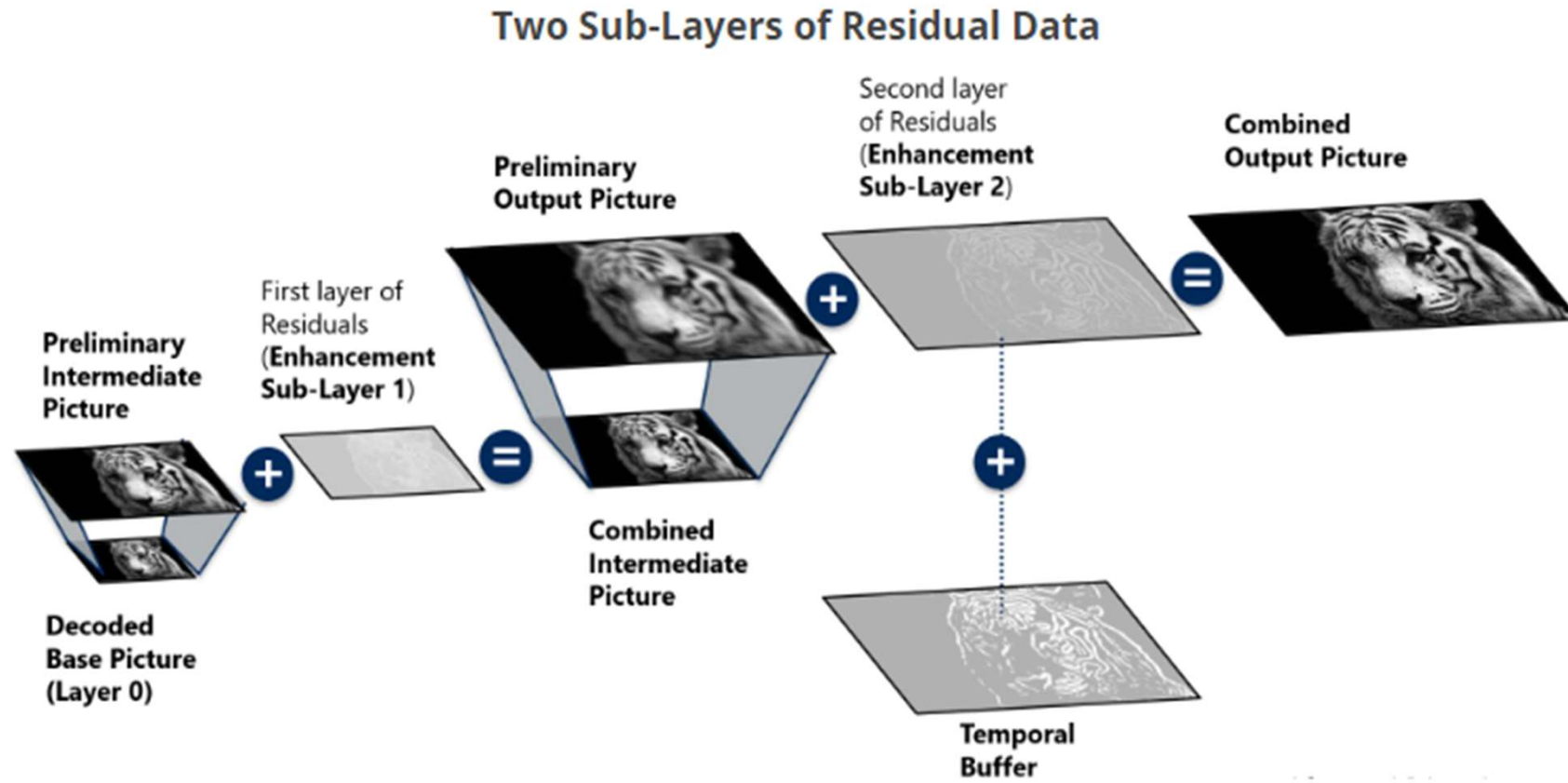
# VVC New Block Partitioning



# LCEVC

- Being standardized by MPEG
- Based on IP from V-Nova
  - More of a pre-processor than a new codec
  - Base layer plus two enhancement layers for additional sharpness and detail
- 2.7X improvement in encoding time vs. HEVC
- Can be used today

# LCEVC Processing





# AVS3

- China-based standard mirroring MPEG developments
- AVS2 for 4K
- AVS3 for 4K/8K
  - Phase one released
  - ~20% bit rate reduction vs. HEVC
- Phase 2 planned for 2021 with further bit rate reductions

# Questions?

# 8K Distribution

# Solving the Distribution Challenge

- Distribution of native 8K is a bandwidth challenge
  - NHK uses HEVC and 80-100 Mbps satellite service
  - Not suitable for wide deployment
- Near term 8K solutions:
  - Smart streaming
  - LCEVC, HEVC, AV<sub>1</sub>
- Longer term 8K solutions:
  - Add VVC, EVC, AVS<sub>3</sub>



# Smart Streaming

- Create highest-quality 8K master
  - Professional upconversion of lower resolution content
- Downscale 8K content to 4K capturing metadata or key AI-assisted information about downscale
- Use metadata/information to smartly encode or content aware encoding using HEVC, AV1 or LCEVC
  - May require minor upgrades to encoders
  - Best suited for streaming delivery
- Use delivered metadata/information to allow TV to upscale back to 8K
- Samsung, Sharp, Fujitsu, Harmonic and others have already demonstrated this

# AI ScaleNet from Samsung

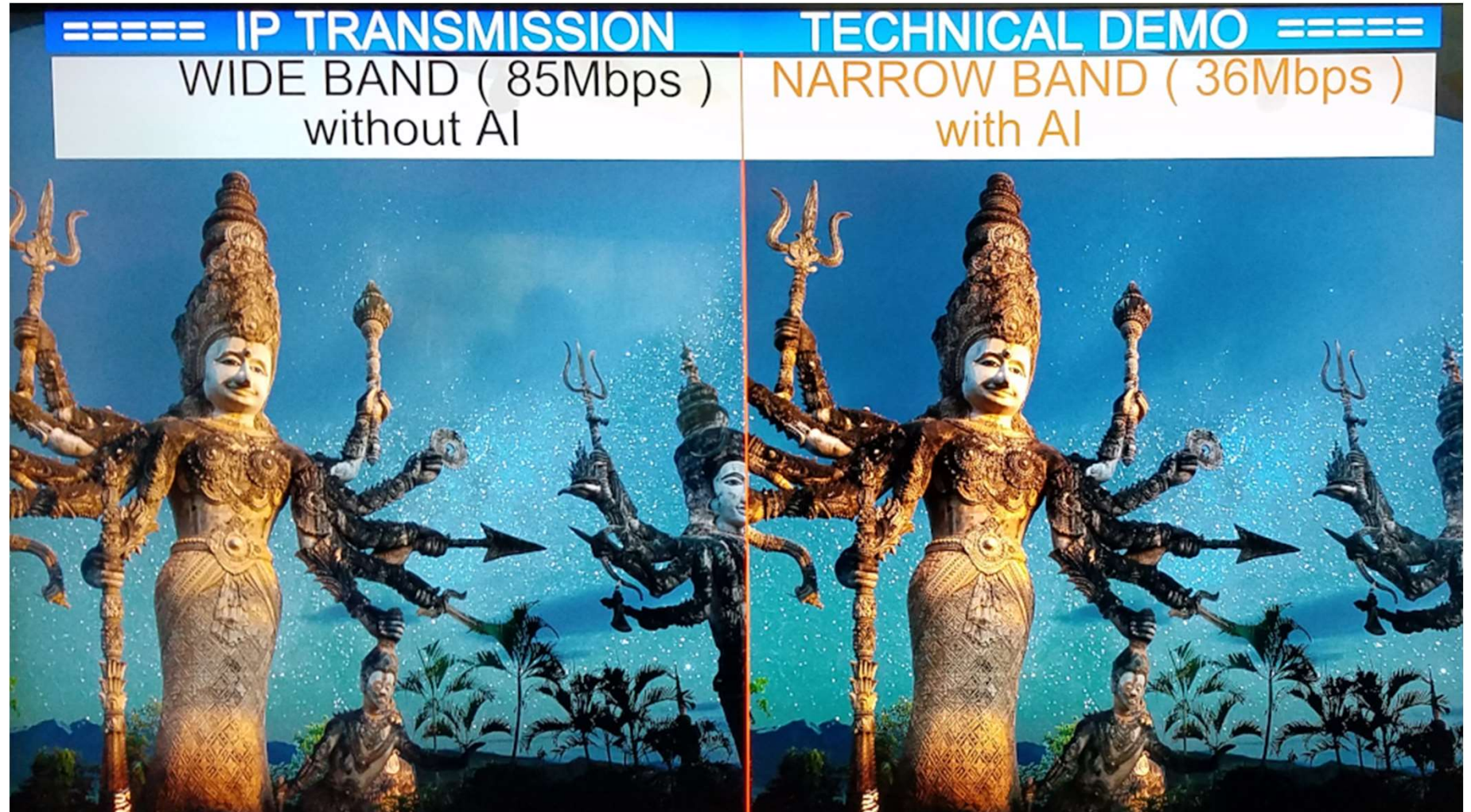
- Provide TV-based AI upscaler algorithm to content creators for:
  - Upscaling of input 2K/4K content
  - Downscaling of finished 8K master
- Downscaling info captured and embedded in HEVC stream for TV to upscale
- Working with Amazon now
  - Likely to start with 4K master/2K distribution to set stage for 8K master/4K distribution later
- Proprietary solution for Samsung TVs
  - Considering offering to standards organizations

# ScaleNet Results

- CES 2020 demo
  - ScaleNet HEVC encoded 4K+info distribution at 15 Mbps
  - Image quality similar to 8K native HEVC encode without ScaleNet at 50 Mbps
  - Netflix VMAF image quality score of 95
    - >80 considered good

# Sharp Results

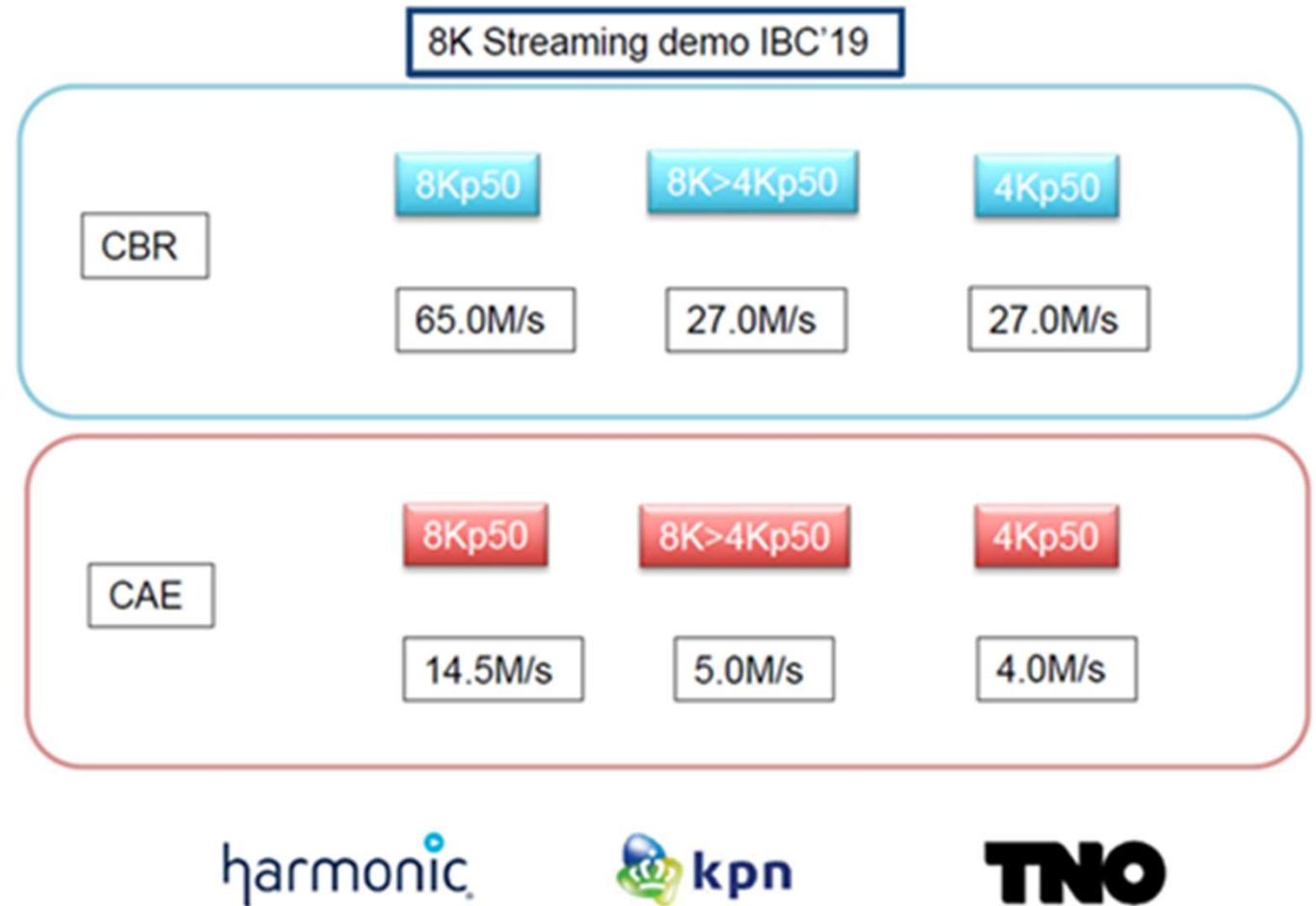
- Shown at CES 2020
- Use for IP and 5G distribution





# Harmonic Results

- From IBC 2019
- Content from a BlackMagic 4K camera and a Red Helium 8K camera were graded by Harmonic (at 1000 nits peak) with three outputs delivered for offline encoding
  - HEVC main10 profile (4K, 8K native, and 4K from 8K native)
  - Constant Bit Rate (CBR) vs. Content Adaptive Encoding (CAE)
- Not yet available for live 8K encoding, but good for VOD





# Fujitsu Result

- Algorithm uses AI to encode areas differently than conventional codecs
- File size reduction of up to  $1/10^{\text{th}}$  conventional encode
- Still early in development



decoded image of video data  
compressed by  
the existing technology



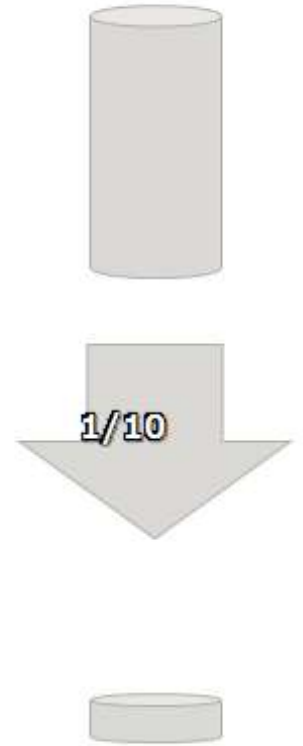
**image quality  
comfortable for humans**

decoded image of video data  
compressed by  
Fujitsu's technology



**image quality required for AI  
to analyze video**

size of  
compressed video data



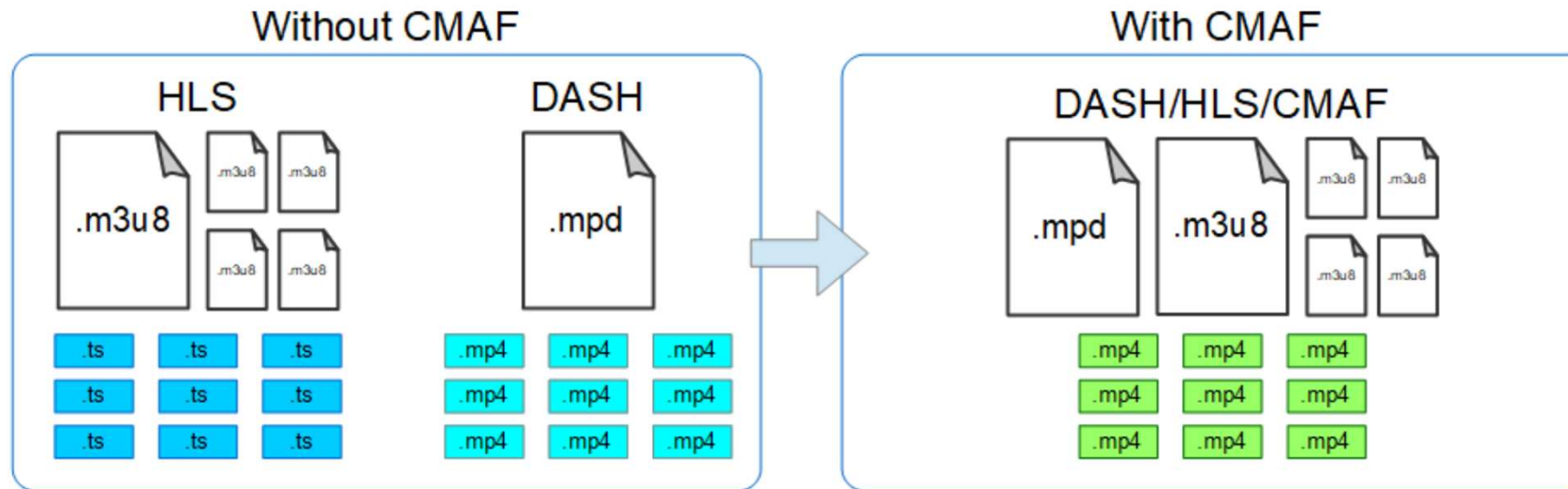
# Satellite and OTA Distribution

- NHK distributing 8K via Satellite now, but high data rate (80-100 Mbps)
  - Also looking at new over the air (OTA) options
- Satellite distribution is on the decline WW
  - DirectTV will not launch any new satellites
  - 8K bandwidth requires full transponder today
- ATSC 3.0 (NextGen TV) and DVB-S2X standards have limited bandwidth and no 8K definition
- IP transport viewed as better alternative for 8K

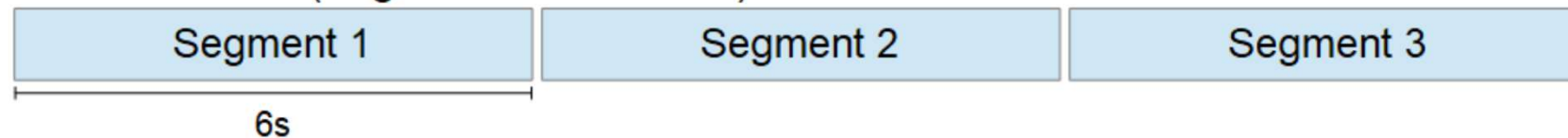
# Internet Delivery

- DASH and HLS are main streaming protocols today
  - Incompatible
  - Can have long latency
- CMAF (Common Media Application Format) to the rescue
  - Allows creation of one media file in .mp4 container for HLS and DASH streaming
  - Adds chunking to reduce latency to ~1 sec.

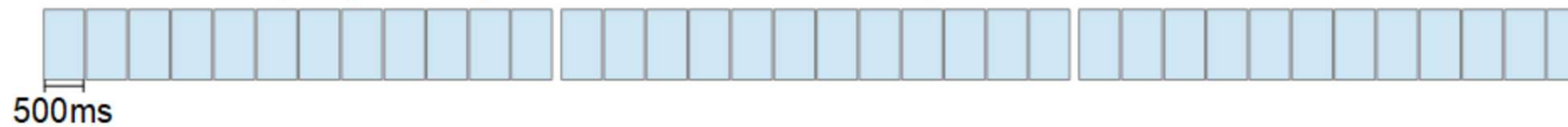
# CMAF



Without CMAF (Segment duration 2-6s)



With CMAF (Segment split into chunks of 500ms)



# 5G Features

- Uses new RF encoding scheme to increase efficiency, provide more bandwidth and be more robust vs. 4G

	5G low-band	5G sub-6	5G mm Wave
Line of sight	No	No	Yes
Pentrate walls, trees, etc.	Yes	Yes	No
distance	Longest	long	short
data rates	low	medium	high

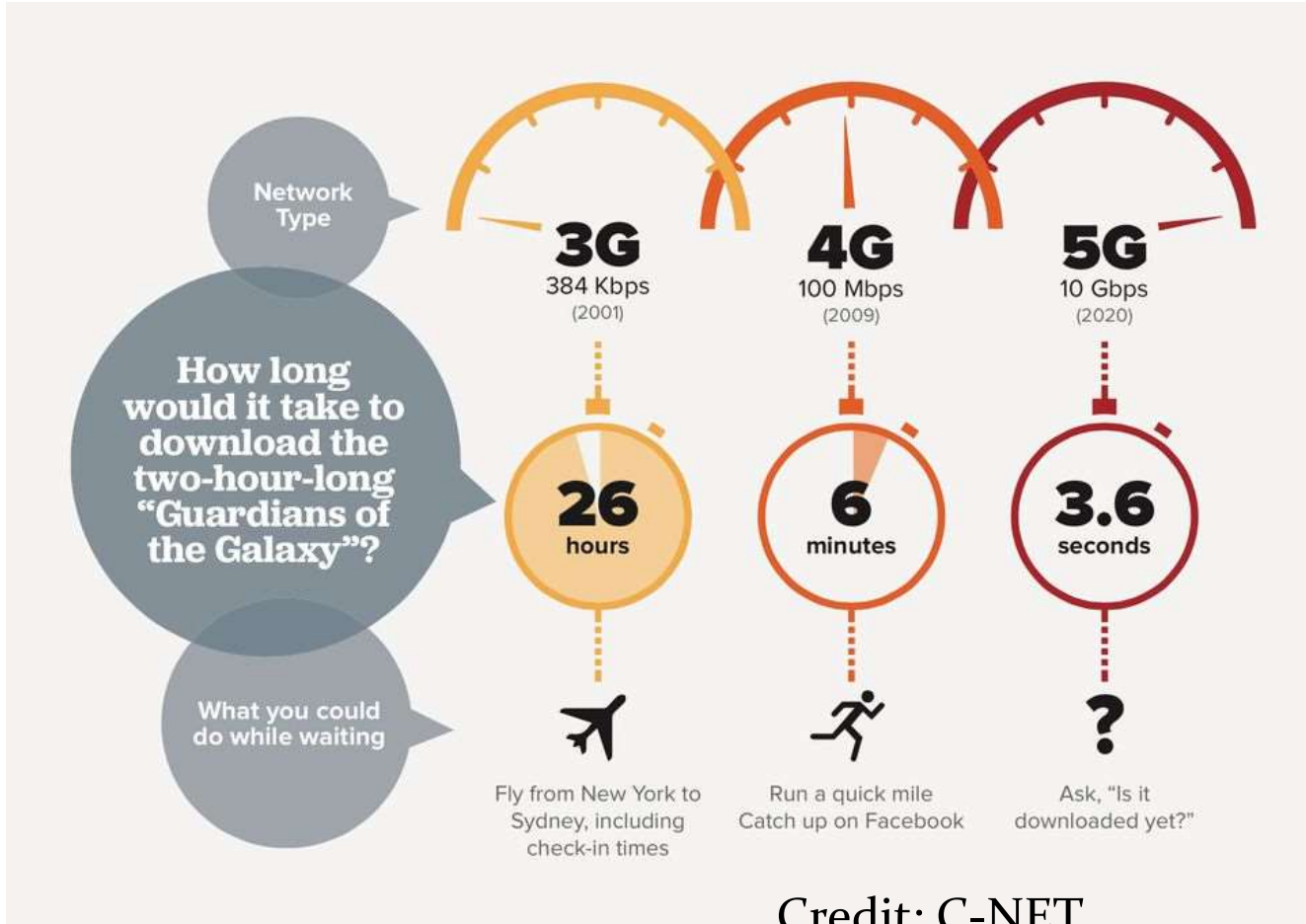




# 5G Variations

- 5G vs 5G NR (New Radio)
  - 5G NR means mm Wave plus sub-6GHz RF Bands
  - Pure 5G mm Wave only (This is where the most Hype is)
- 5G non-standalone (NSA) vs. 5G standalone (SA)
  - NSA is mmWave add-on to 4G network
  - SA uses 5G Sub-6 GHz instead of 4G, plus mmWave
  - Some 5G services are sub-6GHz only (T-Mobile, others)

# Why the Hype about 5G?



- #1 Download Speed
- #2 Short latency (~1ms)
- #3 Far more users can access simultaneously (IoT) (1M/km<sup>2</sup> vs 4000/km<sup>2</sup>)
- Also, Technology Push:
- #4 Chip makers get to sell new chips to phone makers
- #5 Phone makers get to sell new phones to consumers

# Realities of 5G

- mmWave 5G will mainly be for backhaul, private campuses, commercial applications
- Sub-6 will be the main consumer roll out

	8K/30	8K/60
Verizon 5G to the home @ 300MB/S (Typical)	>59:1	>142:1
Verizon 5G to the home @ 940 MB/s (Peak)	>19.1	>46:1

Needed compression ratios

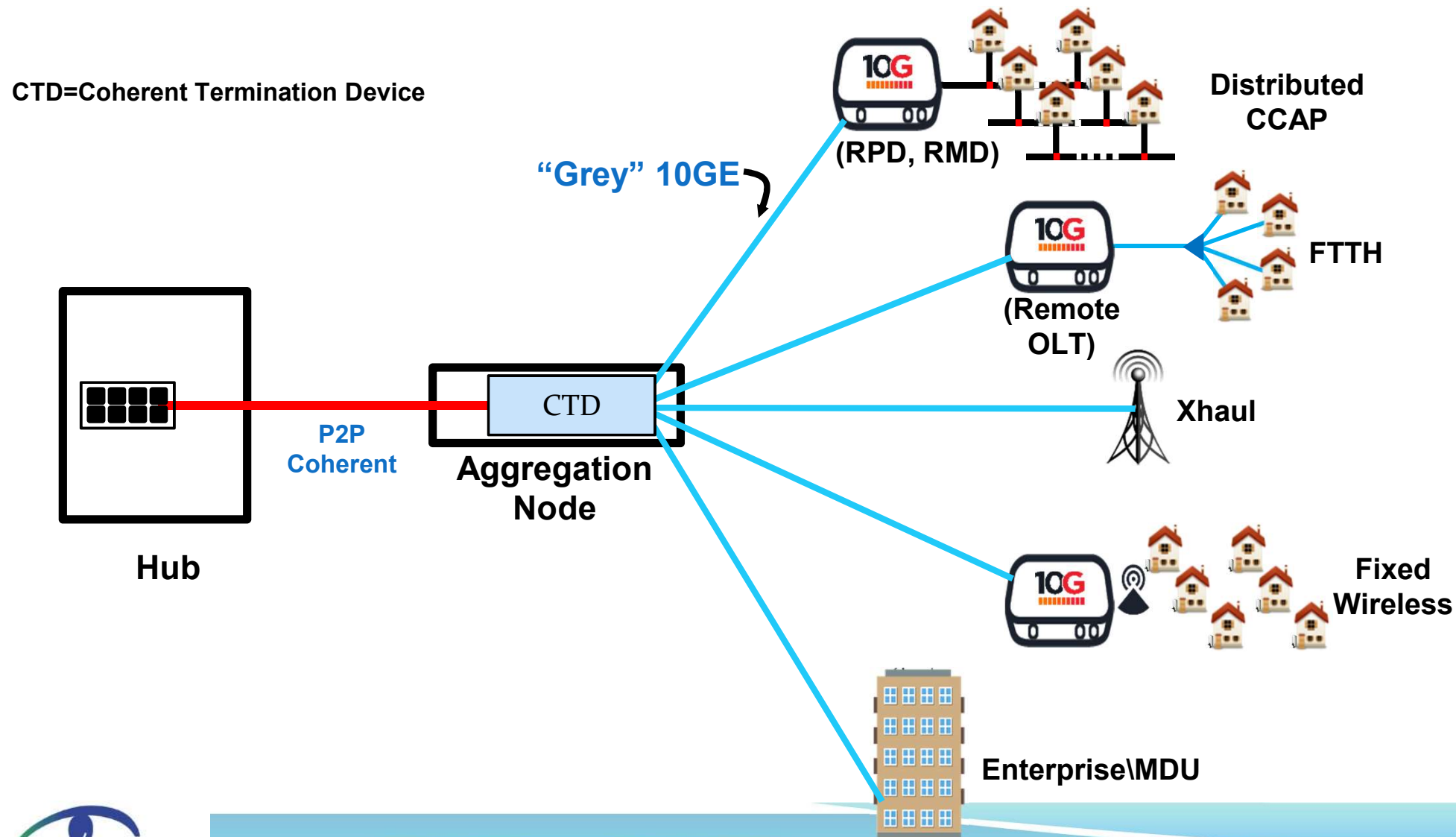
8K/60 4:2:0 10-bit uncompressed = 42.8 Gbps

8K/30 4:2:0 10-bit uncompressed = 17.8 Gbps

# Cable Distribution

- In middle of upgrade to 10Gbps fiber network
  - Improves speed (10X; more reliable, better security, lower latency)
- Actual data rates in home will depend on
  - Number of homes in residential network
  - Type of connection (copper or fiber)
  - Homes activity at any time
- 10G network upgrade to be coupled with dual-channel Wi-Fi 6 roll out
  - Will double data rates from cable box to wireless devices
  - Probably > 1 Gbps

# Converged Optical Network



**100 Gbps  
backhaul capacity**

**10 Gbps to each  
service group**

**Smaller service  
groups**

**More capacity per  
home**



# 8K Streaming Prospects

- Streaming was the leading platform for 4K
  - Expect the same for 8K
- To begin, OTT providers need
  - Smart encoding or new codecs
  - Critical mass of 8K TVs and decoders
  - Native 8K content or superior upscaled workflow
- Existing 8K content
  - NHK broadcasting by satellite
  - The Explorers and YouTube via streaming
  - IMAX (an 8K Association member)
- Many already considering
  - Chili, Megogo, Rakuten
- Streaming wars create opportunity for someone to create a differentiated 8K service



# Distribution Summary

- Smart streaming will significantly reduce 8K data rates from 80 Mbps to mainstream streaming levels of 15-25 Mbps
  - Standards needed for wider adoption
- New codecs like EVC AV1 and LCEVC could be deployed soon
  - VVC more likely for 2022
- Satellite and over the air distribution will be long term if ever
- 5G is overhyped for consumer 8K adoption
- Cable networks are better positioned for streaming service delivery
- Limited streaming services may start in 2020
  - Bigger players enter in 2021/2022

# Questions?

# 8K Playback

# Playback Devices

- Unlikely that a new 8K Blu-ray disc format will be developed for playback
- USB-based NVMe flash memory can offer real time playback
- No set-top-boxes (other than for NHK) or USB streaming stick support 8K yet
- First AVRs with 8K pass thru and 8K upscaling here (Marantz and Denon)
- PS5 and Xbox Series X will have 8K support
  - Arriving by end of 2020



# Uncompressed Data Rates

Horizontal Resolution	Vertical Resolution	frame rate	bits/color	Color sampling	Uncompressed data rate (Gbps)
7680	4320	24	10	4:2:0	11.94
7680	4320	24	12	4:2:0	14.33
7680	4320	30	10	4:2:0	14.93
7680	4320	24	10	4:2:2	15.93
7680	4320	30	12	4:2:0	17.92
7680	4320	24	12	4:2:2	19.11
7680	4320	30	10	4:2:2	19.91
7680	4320	24	10	4:4:4	23.89
7680	4320	30	12	4:2:2	23.89
7680	4320	24	12	4:4:4	28.67
7680	4320	30	10	4:4:4	29.86
7680	4320	60	10	4:2:0	29.86
7680	4320	30	12	4:4:4	35.83
7680	4320	60	12	4:2:0	35.83
7680	4320	60	10	4:2:2	39.81
7680	4320	60	12	4:2:2	47.78
7680	4320	60	10	4:4:4	59.72
7680	4320	120	10	4:2:0	59.72

# Wired Options

- HDMI 2.0 = 14.4 Gbps
- HDMI 2.1 = 48 Gbps (144.3 Gbps with 3:1 DSC)
- DisplayPort 1.2a = 17.28 Gbps
- DisplayPort 1.3/1.4 = 25.9 Gbps
- DisplayPort 1.4a = 76.8 Gbps with 3:1 DSC
- DisplayPort 2.0 = 77.3 Gbps (232 Gbps with 3:1 DSC)
- Thunderbolt 3 = 16 Gbps
- Thunderbolt 4 = 32 Gbps
- USB-3 = 17.28 Gbps (DisplayPort 1.2a Alt Mode)
- USB-4 = 77.3 Gbps (DisplayPort 2.0 Alt Mode)



# HDMI

- HDMI will be the major in-homed wired solution
- HDMI 2.0 ok for 8K/30; 2.1 needed for 8K/60
- All HDMI 2.1 features are optional
  - Need to be very careful to check feature set
- New Ultra high speed (Category 3) HDMI cables needed for 8K
- Display Stream Compression (up to ~3:1) is now allowed too (optional)
- New signaling technology – Fixed Rate Link (FRL)
  - Backward compatible to HDMI 2.0 and older source devices

# HDMI 2.1 Features Overview

- 4K/120, 8K/60 and resolutions up to 10K
- Uncompressed and Compressed Support
- Fixed Rate Link (FRL)
- Dynamic HDR - supporting various industry formats
- 48 Gbps Bandwidth
- New Ultra High Speed HDMI Cable
- Enhanced Audio Return Channel (eARC)
- Gaming and Media Features
  - Auto Low Latency Mode (ALLM)
  - Variable Refresh Rate (VRR)
  - Quick Frame Transport (QFT)
  - Quick Media Switching (QMS)

## DSC SUPPORT DESIGNATIONS

- 4K100<sub>A</sub> – supports uncompressed mode
- 4K100<sub>B</sub> – supports compressed mode
- 4K100<sub>AB</sub> – supports both
- 4K120<sub>A</sub> – supports uncompressed mode
- 4K120<sub>B</sub> – supports compressed mode
- 4K120<sub>AB</sub> – supports both
- 8K50<sub>A</sub> – supports uncompressed mode
- 8K50<sub>B</sub> – supports compressed mode
- 8K50<sub>AB</sub> – supports both
- 8K60<sub>A</sub> – supports uncompressed mode
- 8K60<sub>B</sub> – supports compressed mode
- 8K60<sub>AB</sub> – supports both

# Wi-Fi

- Wi-Fi 6 routers and devices now rolling out
- Uses same 2.4 and 5 GHz bands but
  - increases speed
  - Enables bonding of channels
  - Reduces latency
- Wi-Fi 6E just approved for the 6 GHz band
  - More speed and capacity
- Should be fine for 8K streaming

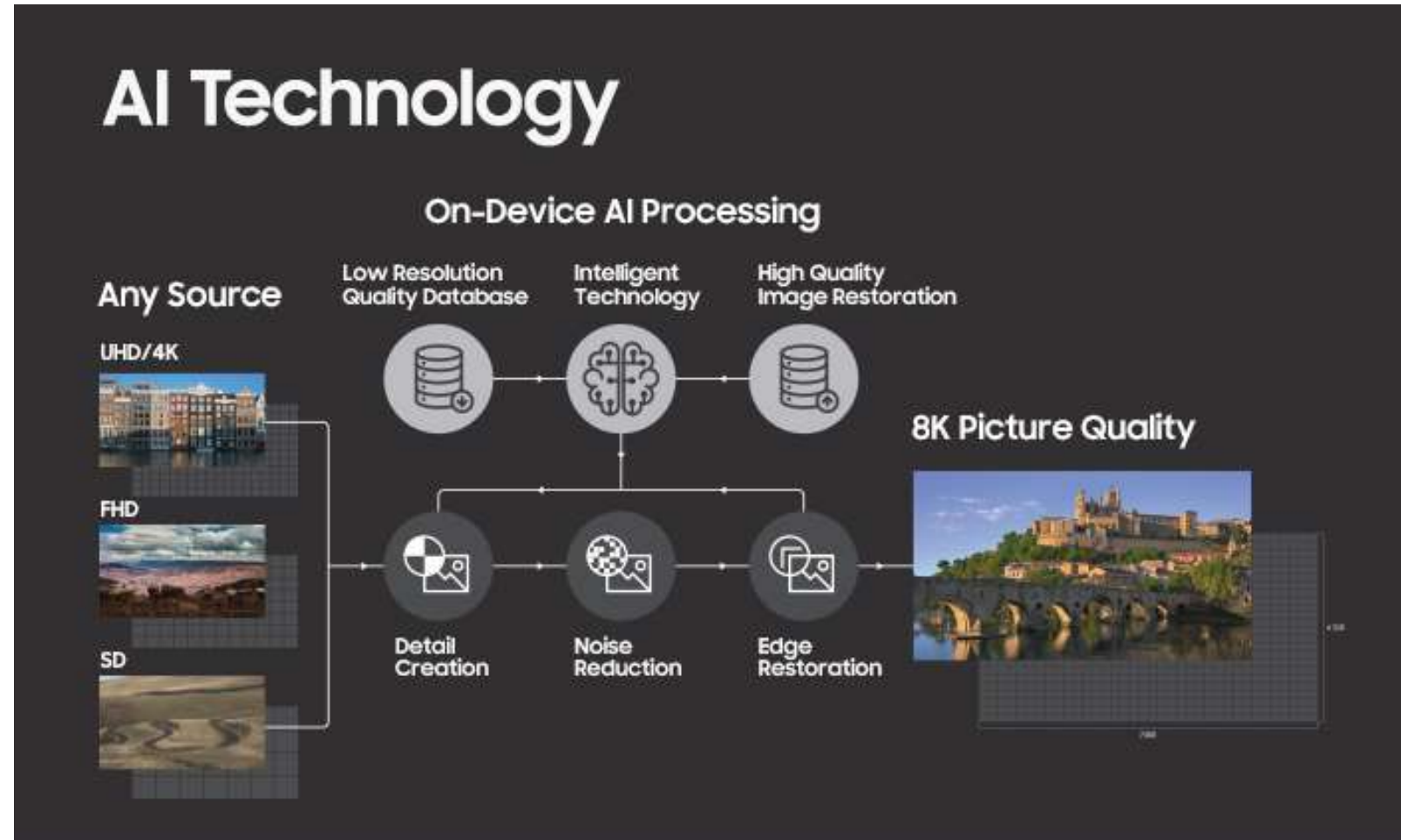


# Questions?

# 8K Display

# AI-Based Upscaling

- AI-Based Upscaling will be key to value of 8K TVs
  - Smart streaming content will particularly benefit
  - All major 8K TVs now offer some version of this



# Upscaling (Image Restoration)

- Modern upscaling is much different than past upscaling algorithms
  - Past used nearest neighbor type scaling
  - Now machine learning and neural network (AI) type algorithms offered by top tier players
- Algorithms very good for 4K, good for 2K and OK for 720/SD content
  - Will continue to improve over time with updates for TV
- Good upscaling is a key differentiator and selling point to overcome lack of native 8K content concern

# 8K Devices

- TVs main device today
- Monitor offered by Dell
  - Sharp and others may enter in 2020
- 8K VR headsets (4K per eye) expected in 2020
- 8K digital signage here today
- 8K screens in laptops possible in 2021/2022
- 8K screens in phones – probably not



# 8K TV Technology

- 8K TVs can be offered with
  - LCD (55" to 120")
    - Dual-Cell (millions of zones)
    - miniLED backlight (thousands of zones)
    - FALD backlight (hundreds of zones)
    - Edge backlight (dozens of zones)
  - OLED (77", 88")
  - MicroLED (236" to 440")
    - Modular (0.6mm to 1.1mm pitch)
  - In development
    - QD on OLED (2021/2022) (early 8K prototype by Samsung Display)
    - EL OLED (?) (4K prototype by TCL)

# Dual Cell

- 4K full color front panel; 4K monochrome back panel; single zone backlight
  - 8K/4K prototype
- Signal luminance drives monochrome panel
  - 2M dimmable zones (8M on 8K versions)
- Trade offs:
  - Great black levels
  - No haloing
  - Lower efficiency (higher power)
  - Higher cost
- Hisense commercializing 4K (65" to 98")
  - Not clear if others will follow
  - Not clear if 8K coming



# MiniLED

- Replace hundreds of conventional LEDs in backlight with thousands of smaller LEDs
  - Emitters in 200-300 micron range
  - Can be manufactured using mostly established techniques
  - 1<sup>st</sup> generation on PCB with passive driving (similar to traditional LED video walls)
  - 2<sup>nd</sup> generation on glass TFT with active matrix driving (like LCDs)
- Number of LED emitters 10K to 100K
  - Number of zones 1K to 10K
- Trade-offs:
  - Improved black levels and reduced haloing
  - Added cost
- TCL first to commercialize with quantum dot film (wide color gamut)
  - Others to follow





# microLED

- Emitters are 20 to 100 microns
  - Good for direct view and AR/VR screens
- New LED manufacturing techniques needed
- New transfer techniques needed
- Large range of solutions today
  - No consensus of best approaches
- Large format commercialized now
  - Samsung The Wall and Sony CLED
  - Many others showing prototypes
- Trade-offs
  - Highest brightness, widest color gamut and long lifetime solutions
  - High cost today
  - Probably long term winner technology



# mini/micro/dual-cell from CES 2020

Brand	MiniLED	MicroLED	Dual-Cell	Status
Samsung		75, 88, 93, 110, 146 - 4K 150, 292 - 8K		commercializing in 2019 expanding sizes in 2020
LG Electronics		145", 4K		prototype
LG Electronics	80", 8K, 4000 nits			prototype
Vizio	85", 8K, 2000 zones			prototype
Hisense			65, 75, 98 - 4K	65" commercialized in China additional commercialization WW coming in 2020
Hisense			32" - 4K 75" - 8K	prototypes
TCL		132", 4K, 1500 nits		prototype
TCL	65 and 75", 4K, 1200 nits, 825 series; PCB backplane			commercialized
TCL	65 and 75", 4K, 1200 nits, Vidrian series; TFT glass backplane			commercializing in 2020
Konka	75", 8K, LCD, 40K LEDs, 10K zones	236" 8K, 2000 nits, 0.68 pitch 118" 4K, 2000 nits, 0.68 pitch		miniLED available now in China microLEDs commercializing in 2020 with 5G (\$240K; \$1,25M)
Changhong	75", 8K, LCD, 5K LEDs, 5K zones, glass backplane, 1000 nits, 1M:1 contrast			mass production March 2020 for China; ~\$7K



# Display Summary

- 8K TVs are coming from all the major TV brands
  - Distribution will vary between NA, China/APAC, EU
- Prices remain high
  - 10.5G fab build out will drive prices lower
- New technologies like miniLED, microLED and dual-cell will continue to invigorate the TV market

# Questions?

# Contact

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