Best Practices in Live HDR Production

EBU Talk, IBC 2019

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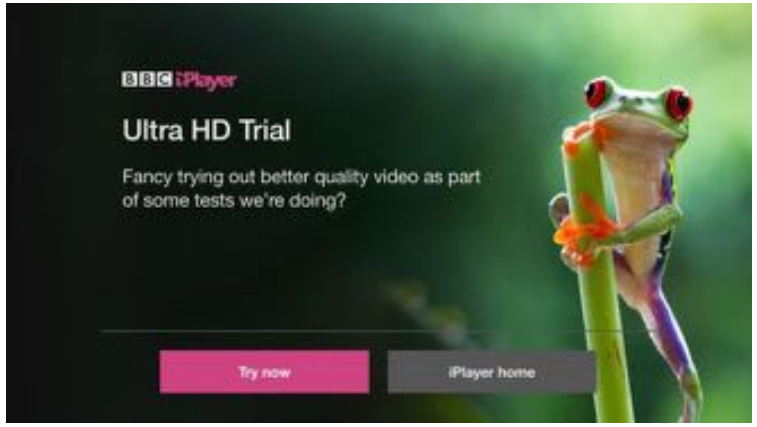
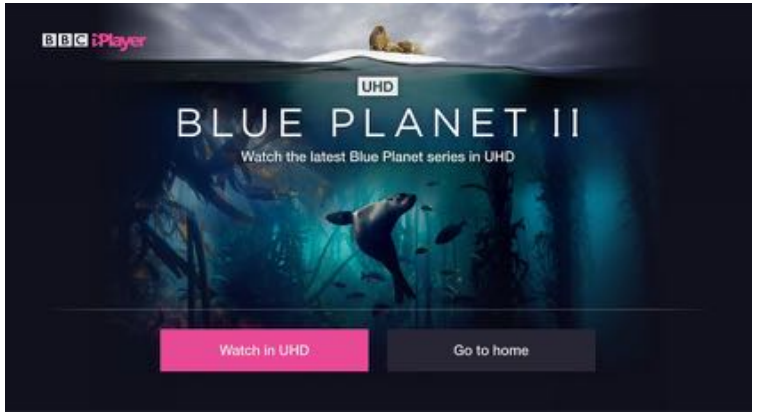
HLG HDR on-demand/non-live workflows well-understood





- BBC iPlayer HLG on-demand trials:
  - Planet Earth II – December 2016
  - Blue Planet II – December 2017
  - Dynasties – December 2018
- Other HDR on-demand launches:
  - Amazon Prime 2015
  - Netflix 2016

Live TV far more complicated…….

- Only one chance to get pictures right
  - Cameras from different manufacturers and different formats must deliver matching pictures
  - No opportunity to colour correct during post-production "grading"
  - Mix of HDR & SDR sources

- Live TV signal formatted to allow real-time delivery
  - 10-bit "baseband" infrastructure
  - Extensive use of mezzanine compression
  - SDR automatically derived from HDR

- Different types of SDR <> HDR format conversions for different applications
  - "scene-light" for cameras
  - "display-light" for graded content & graphics

BBC participated in six major HDR live production trials 2018/2019

- The Wedding of Prince Harry & Meghan Markle (BBC/Sky)
  - Produced but not distributed in UHD HDR

- FIFA World Cup 2018 (BBC/ HBS - Host Broadcast Services)

- Wimbledon Tennis Championships 2018 (BBC/WBS - Wimbledon Broadcast services)

- EBU UHD HDR HFR European Championships (Berlin) 2018
- FA Cup 2019 Quarter, Semi and Finals

- Wimbledon Tennis Championships 2019

Extensive testing ahead of 2018 FIFA World Cup

- 17th Feb FA Cup 5th Round West Bromwich v Southampton
- 8th April British Gymnastics
- 22nd April York City Knights v Catalans Dragons
  - First public announcement
- 19th May FA Cup Final Chelsea v Man Utd
- 9th June World Cup Test event
  - First chance to test the whole chain

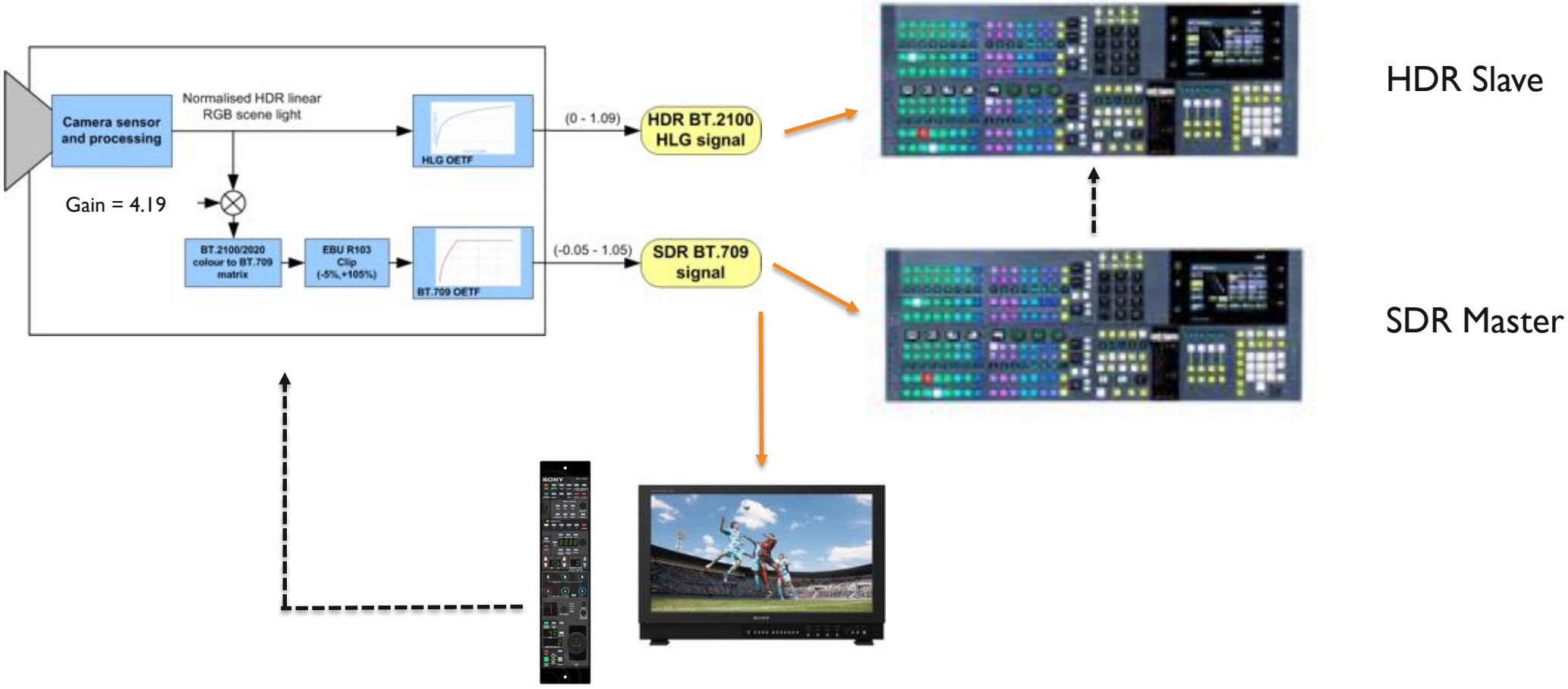
Each trial has further developed the production workflow

- 2018 trials used parallel HDR/SDR production workflows to ensure SDR unaffected by HDR production
  - Enabled through dual HDR/SDR outputs from cameras
  - Cameras usually shaded in SDR

  - 2018 European Championships (EBU) focused on HFR and NGA, but also trialed shading cameras in both HDR and SDR

- 2019 trials focused on establishing a single HDR production workflow, with SDR BT.709 outputs derived from HLG HDR programme output

HDR & SDR parallel production workflows - 2018

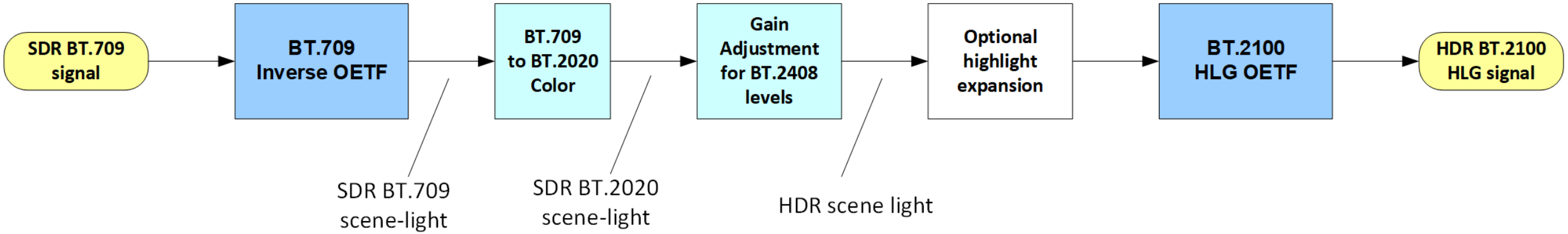


Format conversion terminology – see ITU-R report BT.2408

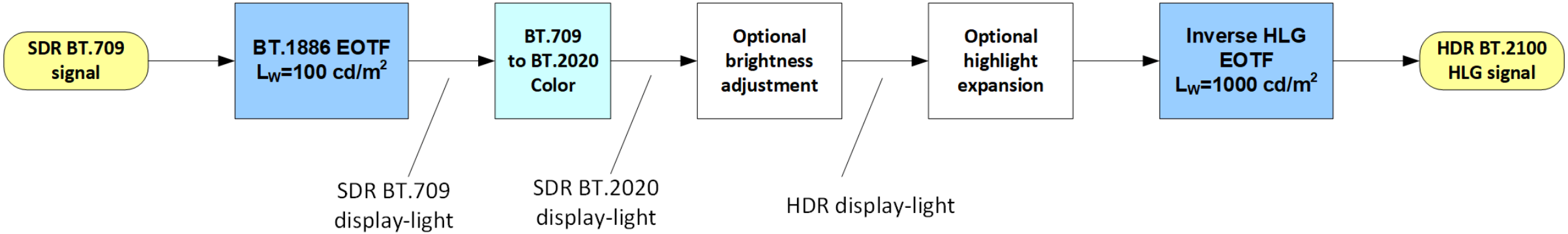
- **Direct-mapping** refers to the process of simply placing SDR content into an HDR signal container, at the correct signal level.
  - Typically 100% SDR > "HDR Reference White", 75% HLG signal
- **Up-mapping** similar to direct mapping but SDR highlights given a small 'boost' to better match the appearance of a native HDR signals
- **Down-mapping** is the opposite of up-mapping. HDR signals converted to SDR by compressing the HDR signal highlights
- **Hard-clipping** (less common) can also be used for HDR to SDR conversion. Can deliver brighter SDR images and graphics, but any highlights captured by HDR cameras are clipped.

Example scene-light vs. display-light conversion – colours differ slightly!

Scene-light conversion preserves camera sensor colours: use for matching cameras

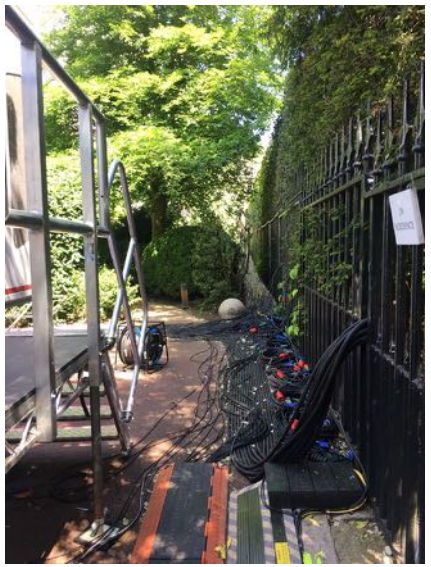


Display-light conversion preserves displayed colours: use for graded content and graphics



The Wedding of Prince Harry & Meghan Markle

Proved that great SDR pictures can be derived from stunning HLG HDR



- BBC deployed 76 UHD HDR cameras
  - 72 cameras output UHD HDR and HD SDR
  - 4 RF cameras UHD HDR only
- Parallel HD SDR (BBC TX) /UHD HDR workflows
- Cameras shaded in SDR
  - Scene-light HLG to SDR conversion for shading HDR only cameras and to feed HD (domestic) production
- UHD HDR switcher slaved to HD SDR switcher
- World HD feed and Sky UHD SDR feed, scene-light HLG HDR to SDR down-mapping
  - Must closely match SDR cameras used by other broadcasters
  - Estimated 1.9 billion viewers - 25% of world population

The FIFA World Cup

Location 1: Crocus Shopping Mall/ Entertainment Centre

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Location 2: Red Square


Augmented Reality Studio

A complex mix of HDR and SDR production formats

- FIFA UHD HDR feed announced late in the process
  - BBC studio already specified as HD only
- Where practical studio facilities upgraded from SDR 1080i to SDR 1080p/50
  - Up-converted well to 2160p/50
- Scene-light conversion from Sony's S-Log3 (HBS's format) to colour match our BT.2100 HLG
- Scene-light SDR to HDR up-mapping for studio cameras and replays
  - To colour match main match coverage in HLG
- Display-light SDR to HDR direct mapping for graphics
  - Preserves FIFA colour branding

Wimbledon 2018 & 2019 Tennis Championships

Proved good colour match achievable between BT.2100 HLG and BT.709 cameras

- Similar to Royal Wedding & FIFA World Cup workflows
  - Parallel HD SDR and UHD HLG HDR workflows
- Wimbledon Broadcasting Services provided UHD HLG HDR feed of Centre Court
- 38 cameras (2018)- mixture of BT.2100 HLG HDR and SDR BT.709 specialist cameras
- BBC Studio feed in HD 1080p/50 BT.709
  - Scene-light SDR to HDR and "up-mapped" to UHD HLG HDR
  - Similar conversion to World Cup – running on different hardware

European Athletics Championships 2018 - EBU

Principally focussed on HFR and NGA

- HDR workflow similar to Royal Wedding and Wimbledon
- Huge collaboration between broadcasters, manufacturers and technology suppliers
- Tested shading in HDR and SDR

Video team

Audio team

Key HDR Production Lessons from 2018

- Parallel HDR/SDR production workflows costly and complex!
  - HDR and SDR camera outputs do not always track one another
  - Signal timing harder

- **Direct-map** SDR graphics according to BT.2408 (Graphics White = 75% HLG)
  - If graphics too bright underlying HDR video can look dull
  - Do not use up-mapping

- **Scene-light** format conversions work well for matching HDR & SDR cameras
  - Relaxing SDR signal clippers to EBU R.103 levels can improve the colour match
  - Up-mapping SDR 1080p cameras to UHD HDR usually works well
    - Use direct-mapping for poorer quality SDR cameras

- Shade cameras by monitoring in SDR
  - Shading in HDR creates images that are difficult to convert to SDR

- HDR to SDR conversion can create excellent SDR pictures

FA Cup 2019

2019 trials developed single UHD HDR workflow for both UHD HDR and HD SDR delivery

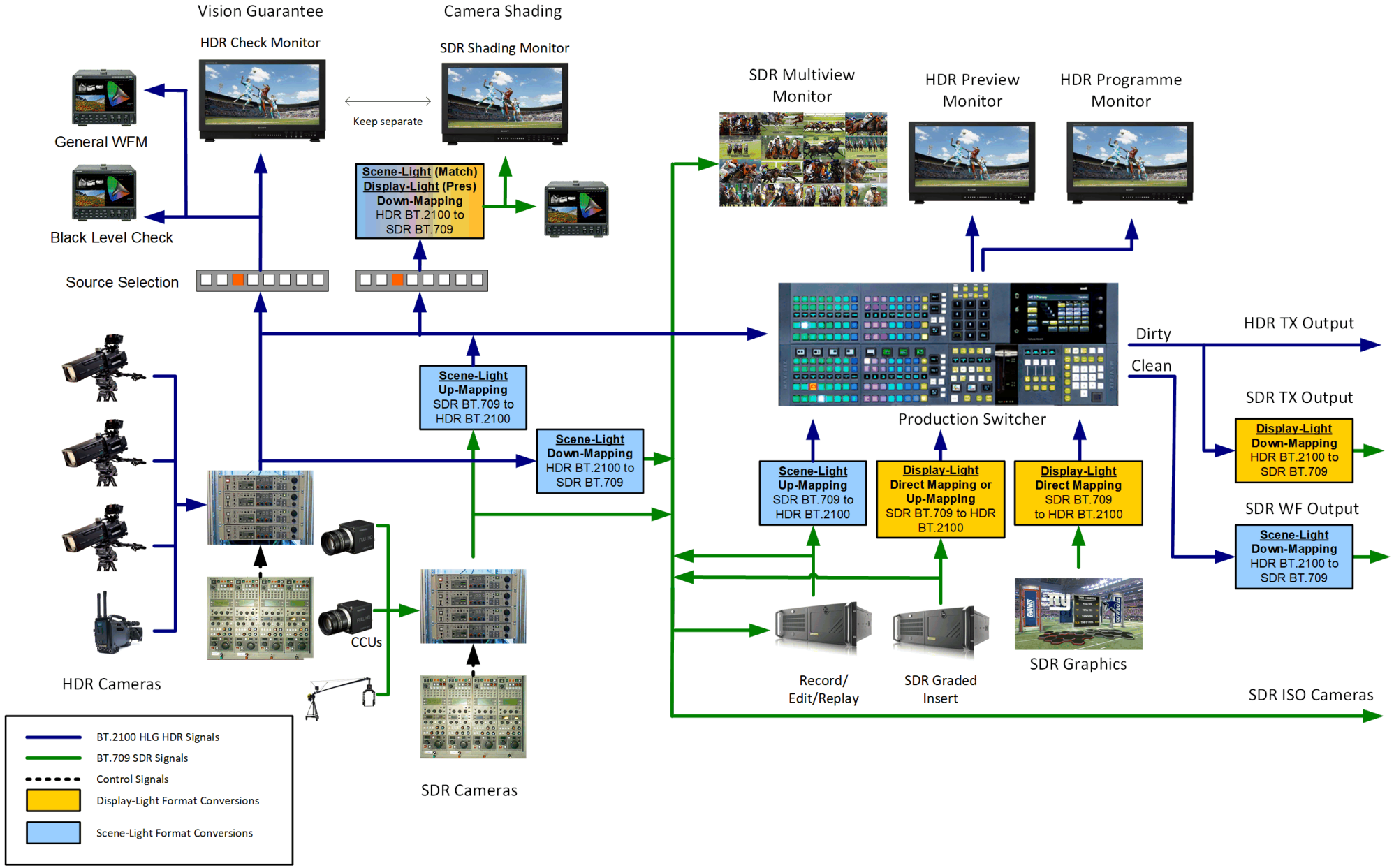
HD SDR coverage derived from the UHD WCG HDR production

- FA Cup Quarter-Final – Millwall v Brighton, "The Den"
  - HD only. No public UHD on iPlayer
- FA Cup Semi-Final - Manchester City v Brighton & Hove Albion, Wembley
- FA Cup Final – Manchester City v Watford, Wembley
  - BBC "host" broadcaster

FA Cup Final amongst most complex of live TV productions

- 41 cameras in total
  - 4 HDR 1080p RF cameras
  - 4 SDR 1080p super slo-mo cameras
  - 2 SDR 1080p ultra slow motion cameras
  - Spidercam, polecam, crowd-cam, robocams, helicam
- "VT" replays limited to 8-bit SDR BT.709
- Proved that with the right workflow, possible to produce artistically pleasing images at both UHD HDR and HD SDR

FA Cup coverage extremely complex – mix of cameras & formats



Key HDR production lessons from 2019 – Part 1

- Great HDR and SDR pictures possible from single HDR workflow
  - Complex productions require a lot of HDR<>SDR format converters!

- HLG produces very natural looking pictures
  - *Some genres will require use of HDR camera painting controls to deliver desired artistic "look"*

- Shade by monitoring in SDR, *but do not use SDR outputs from HDR cameras!*
  - HDR and SDR outputs generally don't track sufficiently well
  - Ideally shade in SDR via a dedicated HDR to SDR converter
    - HLG backwards compatible picture (BT.2020 gamma 2.2 display) can be used in controlled lighting

- 1000 cd/^{2} HDR display too bright alongside critical SDR shading monitors
  - In confined space reduce HLG nominal peak to 600 cd/m^2 (gamma 1.1)

Key HDR Production Lessons from 2019 – Part 2

- On HDR to SDR converted programme output:
  - Use display-light conversion on "dirty" feeds to maintain the colour of embedded graphics e.g. domestic TX
  - Use scene-light conversion on "clean" feeds to colour match third party SDR cameras e.g. World feed from host broadcaster

  - Use down-mapping to allow SDR viewers to benefit from HDR production
    - Reduces amplitude of embedded graphics (~80% to 90%) to give room for some "highlights"

  - Use hard-clipping to match typical SDR "live" production
    - Loses benefits of HDR production, but allows embedded graphics at 100%

  - Add some "sharpness" on SDR output
    - HDR> SDR conversion reduces contrast, in images and thus subjective level of detail
- HDR line-up signals needed that survive HDR > SDR format conversion

Summary of recommended conversion types (and advert)

	Signal Source	BBC Conversion LUT	Conversion Type		SDR to HDR		HDR to SDR		HDR to HDR
			Scene-Light	Display-Light	Direct Mapping	Up-Mapping	Hard Clipping	Down-Mapping	Conversion
Graded Content	SDR graded inserts [1]	5		✓		✓			
	SDR graded programmes	3		✓	✓				
	HLG graded content	8		✓				✓	
	PQ graded content	1 or 2		✓					✓
Camera to switcher	**SDR BT.709 camera [2]**	**6**	✓			✓			
	S-Log3 camera	**10**	✓						✓
	"S-Log3 Live" [2] camera	**11**	✓						✓
Camera to SDR shading [3]	HDR camera (display-light priority)	8		✓				✓	
	HDR cameras (scene-light priority)	12	✓					✓	
	SDR camera (HDR workflow) SDR > HDR > SDR (display-light priority)	6 and 8	✓	✓		✓		✓	
	SDR camera (HDR workflow) SDR > HDR > SDR (scene-light priority)	6 and 12	✓			✓		✓	
Graphics	**SDR matching colour branding**	**3**		✓	✓				
	SDR matching in-vision signage	**4**	✓		✓				
Programme Output	SDR "dirty" (with graphics)	8		✓				✓	
	SDR "clean" (no graphics) for mixing with unilateral SDR cameras [4]	12	✓				✓		
	PQ for onward distribution	7		✓					✓

Note 1: Modest highlight "boost" to improve match with native HDR (100% SDR -> ~83% HLG)
Note 2: Small highlight "boost" to improve match with native HDR cameras (100% SDR -> ~79% HLG)
Note 3: Display-light shading where "dirty" output has priority, scene-light shading where "clean" output has priority
Note 4: Emulates SDR camera with some soft clipping of highlights

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- EBU members lookout for HDR Production Workshop, NRK Oslo, 18 – 20 November

Thank you

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