SMPTE MEDIA TECHNOLOGY SUMMIT

PUTTING THEORY INTO PRACTICE

Innovations in Camera Technology for Live Production

Film-Look in live production – What are the specific requirements and what does an optimal camera look like?

Klaus Weber, Director Product Marketing
Grass Valley

Agenda

- **Film Look / Depth of Field**
  - Multiple Camera Types
  - Color Separation Methods
  - Signal Processing
  - Live Camera Control
  - Multiple Simultaneous Outputs
  - LED Walls
- **Optimized Camera for Film-Look in Live Applications**
  - Imager and Optical Filtering
  - Processing and Workflow
- **Conclusion**

Film Look

- The ‘film look’ is characterized by several key elements:
  - 24p frame rate, usually combined with a shutter angle of less than 360°
  - A shallow depth of field

- At first glance, it might seem logical to use existing digital cinematography cameras to achieve this film look

Simulated image

- They offer exceptional image quality and are readily available, so why not simply utilize them?

Depth of Field

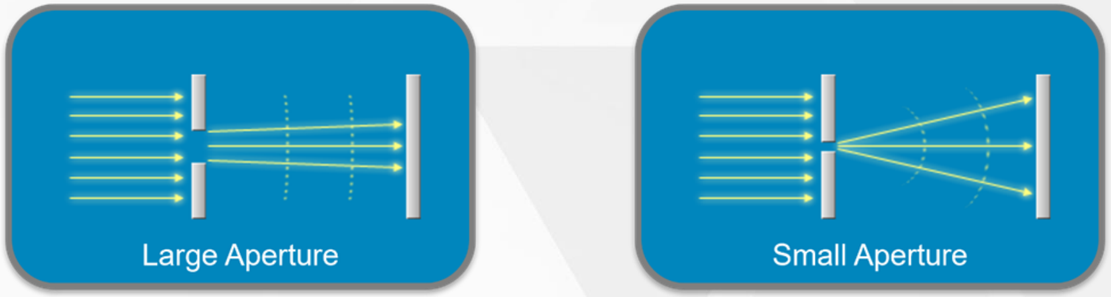
- The shallower depth of field, depends primarily on the focal length of the lens, which in turn depends on the size of the imager
- In live productions, the opposite problem exists with most camera positions

- Even with the small 2/3” imagers, the depth of field is already too shallow for a reliably optimal focus setting

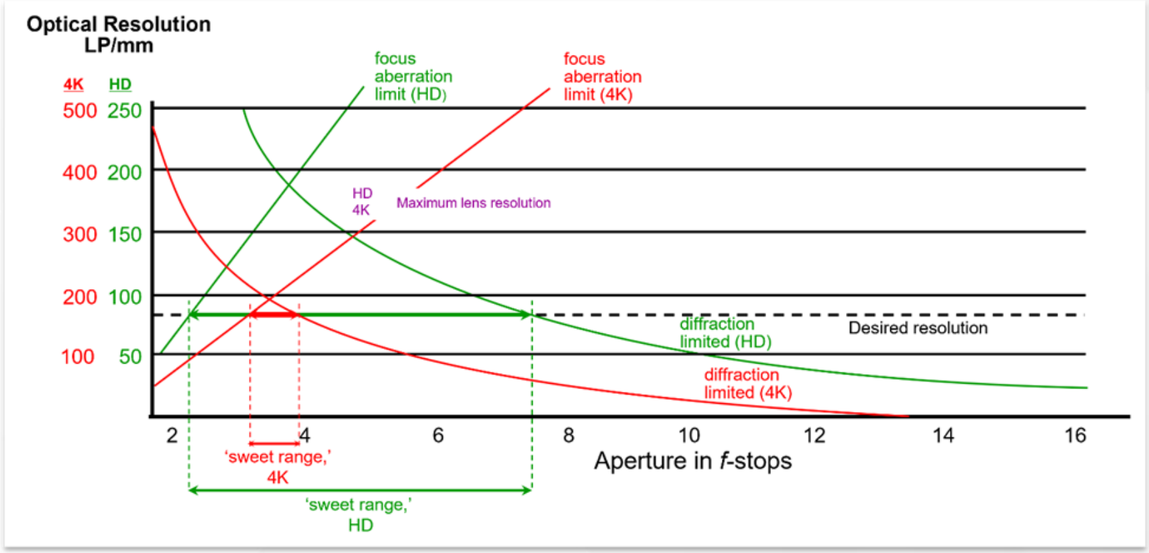
Object conditions, 2.1m height, 100m distance		
Image size	2/3” (d = 11mm)	S35 (d = 27.5mm)
Focal length	260mm	650mm
Lens aperture	DoF	
F.no		
2.8	5.8m	2.5m
4.0	8.3m	3.6m
5.6	11.6m	5.0m
8.0	16.6m	7.2m

Depth of Field

- Why not simply close lens iris?
- Lenses are subject to two primary optical limitations:
  - Aberrations - when iris is wide open
  - Diffraction - when iris is closed down
- The “sweet range of the lens is:
  - For HD resolution, 3-4 f-stops
  - For UHD resolution, ½ f-stop



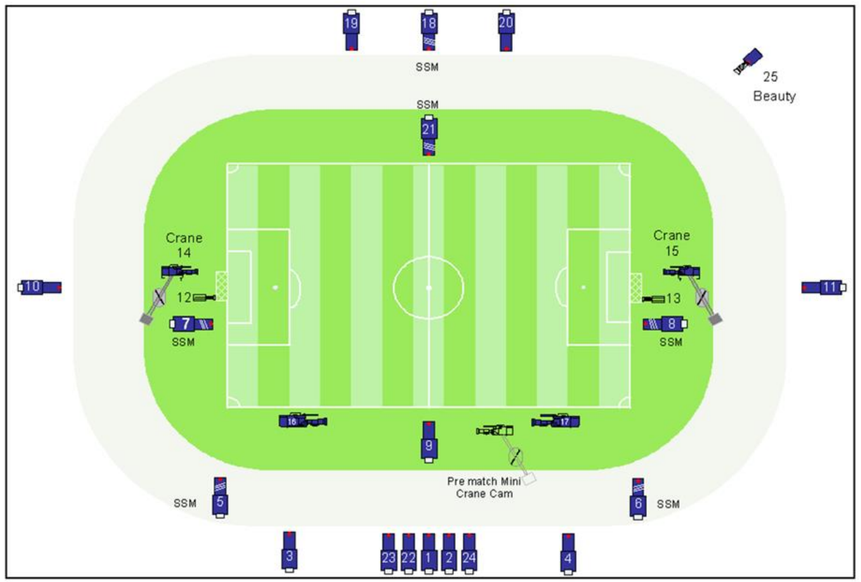
Diffraction depending on lens aperture



Sweet range between aberration limits and diffraction limits

Multiple Camera Types

- Seamless live production need to integrate multiple camera types
  - Each with a specific function—such as standard system cameras with portable or long zoom range box type lenses, super slow-motion cameras, wireless cameras, and compact cameras
- Ensuring a consistent visual appearance across all cameras is essential
  - Maintaining uniformity in color reproduction, gradation, and image sharpness

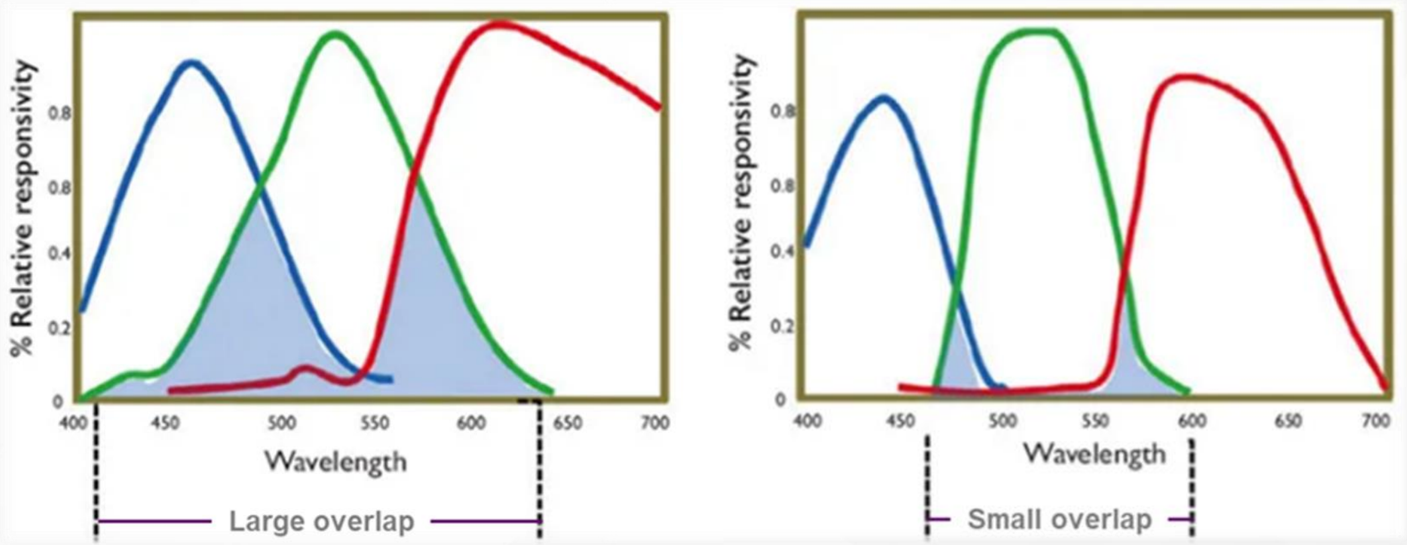


	High and large distance position		Low and short distance position	
	Wide angle	Tele	Wide angle	Tele
Example of camera positions	1, 3, 4	5, 6, 10, 18, 19, 20, 22, 24	14, 15	7, 8, 9, 21
Highest resolution	+	-	o	-
High sensitivity	o	+	o	+
Global shutter	-	+	+	+
High dynamic range	+	o	+	+

+ = Very important / o = Neutral / - = Less important

Color Separation Methods

- A three-imager RGB prism systems and a single-imager Bayer filters—have a different color response leading to a different color reproduction
  - Bayer pattern filters typically offer less selective color separation, resulting in greater overlap between color channels
  - Prism beam splitters in three-imager cameras provide more accurate color separation with minimal overlap



Signal Processing

- The primary distinction between a live application and a digital film production is the time available for image processing

- In live the interval between light hitting the imager and the signal going on-air is extremely limited—typically just one frame
  - This brief window requires highly efficient, real-time processing to produce the final image instantly, as there is no opportunity for post-production adjustments

- Digital cinematography camera's main purpose is to capture and preserve as much information as possible for post-production
  - They are optimized to capture maximum dynamic range and latitude, often in the form of RAW data, allowing extensive manipulation of the image in post
  - Allows to fine-tune the image’s look long after shooting but means that the in-camera processing requirements during capture are less demanding

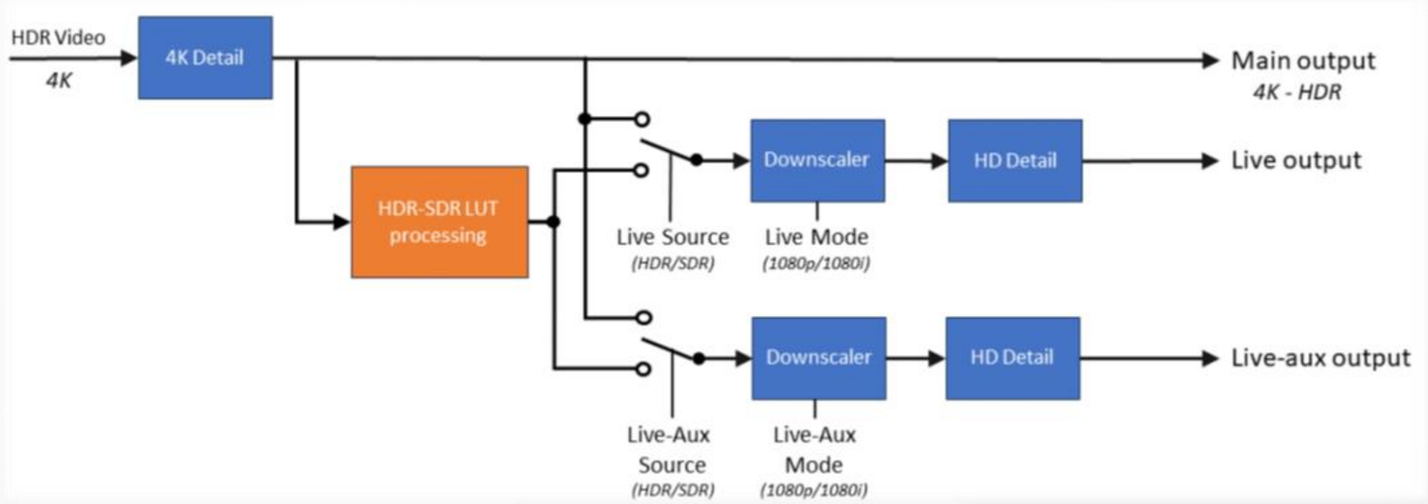
Live Camera Control

- A critical aspect of live production is live camera shading
- Performed by an operator to ensure consistent image quality across multiple cameras in real-time
- Advanced tools have been developed
  - Dedicated, customizable live camera control panels
  - Sophisticated software providing an overview of all cameras and their settings

- These tools allow for precise live adjustments, ensuring a cohesive look despite the different conditions and camera types involved

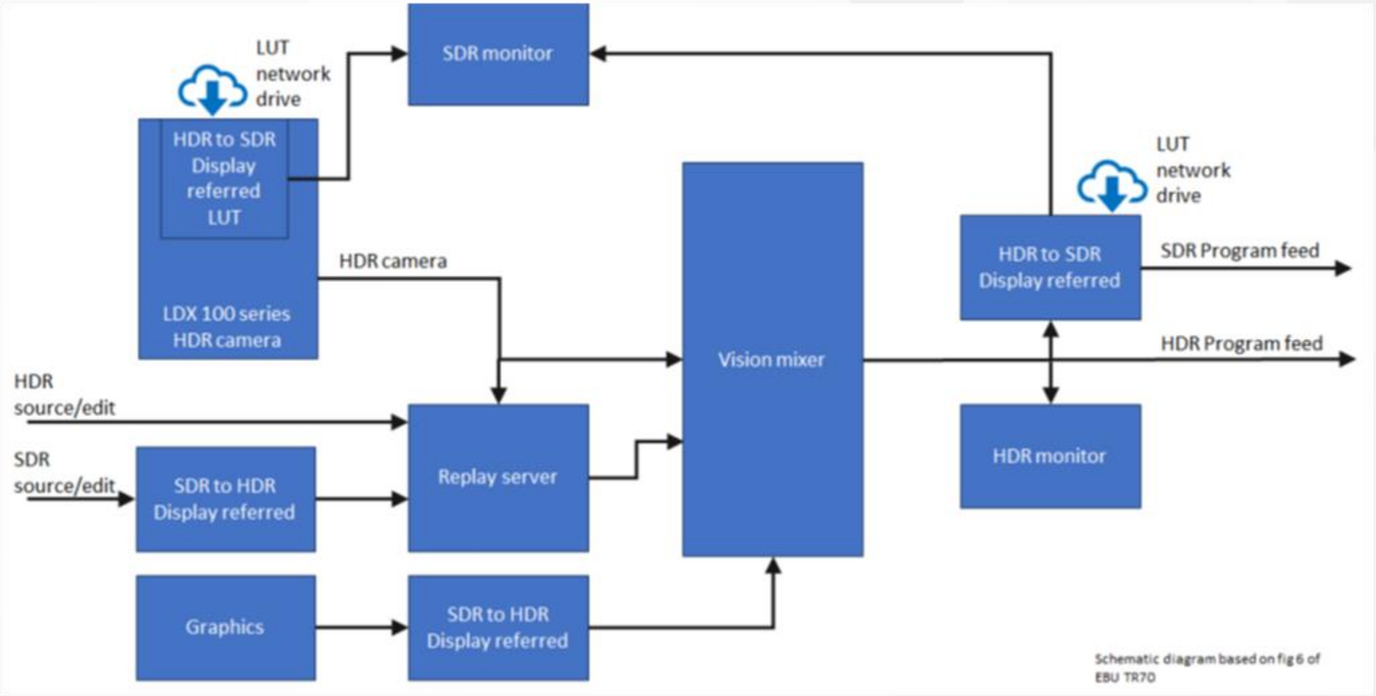
Multiple Simultaneous Outputs

- Live production require simultaneous outputs in various formats and dynamic ranges, tailored to different aspects of the production
- For example:
  - UHD with HDR and Wide Color Gamut (WCG) as main production feed
  - 1080p HDR/WCG - for the Video Assistant Referee (VAR) system
  - 1080i SDR/Rec.709 - for camera shading and ISO feeds / recording



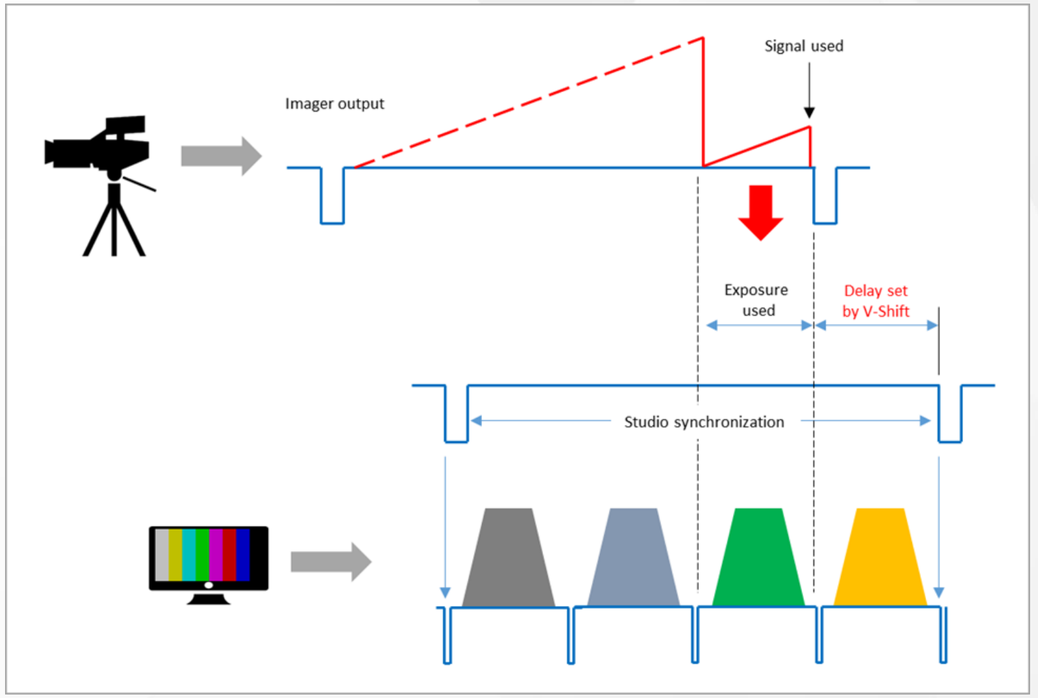
Multiple Simultaneous Outputs

- If a camera can't deliver the required signals, external converters must be used
  - Increases costs but also introduces additional points of potential failure
- This is especially critical in HDR productions, where a simultaneous SDR signal is often mandatory
  - Closed-loop shading
  - ISO signals



LED Walls

- In recent years, LED walls have become a staple in various live production environments
  - In news studios for displaying virtual backgrounds, interview partners, weather forecasts, and other dynamic content
  - In music productions they are integral for showcasing performers and creating immersive show effects often displayed on massive screens for the audience
  - In sports productions, virtual ad replacement on LED banners has become standard practice, providing valuable advertising space



Optimized Camera for Film-Look in Live Applications

What does it look like?

Optimized Camera for Film-Look in Live Applications

- **Imager and Optical Filtering**
- A single S35 CMOS imager with a PL lens mount
  - This combination offers a wide selection of lenses suitable for live production
- A global shutter is not just optional but essential
- A significantly higher pixel count than the standard UHD resolution
  - Enabling oversampling for better modulation transfer function (MTF), requiring less detail correction, leading to smoother, more natural images
- An additional optical low-pass filter (OLPF) for an optimal suppression of aliasing artifacts when working with LED walls
- Imager and processing should support a dynamic range of at least 15 f-stops
  - Ensuring that the camera can capture the full dynamic range expected from the best live cameras on the market without any limitations

Optimized Camera for Film-Look in Live Applications

- **Processing and Workflow**
- The requirements in this area are straightforward, the camera should match the capabilities of current top-tier live cameras with 2/3" image imagers
  - Including all processing features for simultaneous HDR & SDR outputs across different formats, the ability to select from the same color matrices and utilize V-shift functionality for optimized integration in VR/AR applications
  - Differences resulting from variations in imagers and color separation systems must be compensated within the camera, ensuring that both types can operate side by side without users noticing any discrepancies or limitations
  - Connectivity, signal flow, and the flexibility and number of output signals should remain consistent across both camera types, with any differences ideally limited to the image sensors, lenses, and resulting optical characteristics
- This suggests that both cameras were developed on a shared platform

Conclusion

- Key differences between cameras for live and digital film productions are not the size and number of imagers but their approaches to image processing
  - Live productions requires a polished image in real-time
  - Digital film requires capturing the highest possible quality for later enhancement
- Film look in live production is a complex task, requires balancing various elements
  - The optimal camera for this purpose should feature a S35 imager, a global shutter, and advanced real-time processing capabilities with consistent color science
  - The latest advancements in CMOS imaging technology and signal processing, deliver the cinematic quality demanded in live environments
- In summary, while achieving a film-like look in live production presents significant challenges, ongoing innovations in camera technology offer promising solutions