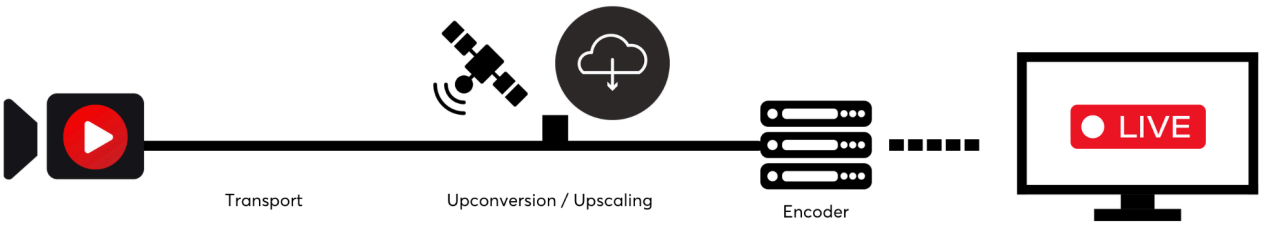
Pixop LIVE

Real-Time AI Video Enhancement and Upconversion for Live Broadcast Workflows



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1. Overview

Pixop LIVE is a GPU-accelerated, real-time video enhancement solution for modern live broadcast workflows. It operates as a drop-in processing node that improves video quality at any stage of the pipeline without requiring changes to existing infrastructure.

Live workflows often rely on compressed, interlaced, or standard dynamic range (SDR) sources that limit output quality, while demand for UHD and HDR continues to grow. Upgrading entire production chains to meet these expectations is complex and costly.

Pixop LIVE addresses this by introducing a real-time processing stage that aligns and enhances video before final encoding. It combines machine learning-based restoration, super-resolution, and format conversion into a unified pipeline that operates within strict latency constraints.

This enables workflows such as HD to 4K upscaling, SDR to HDR conversion (PQ and HLG), and enhancement of legacy interlaced signals, while preserving temporal stability.

The system integrates with standard broadcast and IP-based workflows, supporting both network transport (such as MPEG-TS over SRT) and high-performance in-process interfaces for minimal-latency deployments. Its containerized architecture enables flexible deployment across cloud and on-prem environments.

By normalizing resolution, dynamic range, and signal characteristics prior to compression, Pixop LIVE ensures that downstream encoding operates on a consistent and optimized input. This improves visual quality, increases compression efficiency, and reduces variability in output across different sources, enabling more predictable performance in both contribution and distribution workflows.

Pixop LIVE allows broadcasters and streaming platforms to improve visual quality, extend the value of existing assets, and deliver modern viewing experiences without requiring infrastructure overhaul.

2. The Problem & Opportunity

2.1 Challenges in Live Video Workflows

Live broadcast and streaming workflows operate with heterogeneous inputs, including interlaced video, SDR content, legacy frame rates, compression artifacts, and inconsistent color representation.

These variations arise from complex production environments with different cameras, encoding settings, and transmission constraints. In sports workflows, fast motion, aggressive compression, and challenging lighting further amplify these issues.

To manage this, broadcasters rely on discrete processing tools such as deinterlacers, format converters, color processors, and upscalers. These are typically applied independently within the signal chain.

However, many of these issues are interdependent. Interlacing artifacts affect motion stability and detail reconstruction, while compression artifacts, noise, and temporal instability are closely coupled. Addressing them in isolation often leads to inconsistent results.

In live workflows, strict latency constraints limit the ability to correct these issues iteratively. As a result, inconsistencies introduced early in the pipeline are often carried through to the final encoded stream.

2.2 Increasing Demand for Higher Quality

At the same time, expectations for video quality continue to increase. Broadcasters and streaming platforms are expected to deliver HD, UHD, and HDR content.

Modern displays expose compression artifacts, noise, and instability more clearly, especially in high-motion content such as live sports.

Upgrading entire production chains to meet these expectations is possible, but often requires significant investment and operational complexity.

2.3 The Opportunity: Pre-Compression Normalization

To address these challenges, Pixop LIVE introduces *pre-compression normalization* as a dedicated stage in the live pipeline. This stage operates between contribution and encoding, where the signal is aligned before compression is applied.

The objective is to establish a consistent and optimized input for encoding by normalizing resolution, dynamic range, color space, and temporal stability. Rather than applying isolated corrections, the signal is processed as a unified whole, ensuring that each stage operates on an improved representation of the content.

This approach produces compounding quality gains. Restoration improves the signal prior to super-resolution, enabling more accurate detail reconstruction. Super-resolution then provides a higher-quality spatial foundation for tone

mapping and color processing. Each stage reinforces the next, reducing the risk of propagating or amplifying artifacts introduced earlier in the pipeline.

In contrast, discrete tools applied independently often operate on suboptimal inputs and can introduce inconsistencies between stages. This limits overall quality improvements and can lead to unstable or visually incoherent results after compression.

By consolidating these processes into a single, deterministic stage before encoding, pre-compression normalization establishes a stable and consistent signal. This improves both perceptual quality and encoding efficiency, ensuring that downstream compression operates on content that is already aligned with the target format.

3. Pixop LIVE Overview

3.1 Product Overview

Pixop LIVE is a GPU-accelerated, real-time video enhancement solution for live broadcast workflows. It operates as a dedicated processing node within the signal chain, improving video quality while maintaining deterministic, low-latency performance.

The system uses a unified pipeline that combines restoration, super-resolution, inverse tone mapping, and color management into a single stage. By processing the signal holistically rather than applying isolated corrections, each step operates on an optimized input.

This enables consistent visual quality across a wide range of sources, including compressed, interlaced, and SDR inputs.

3.2 Role in the Live Workflow

Pixop LIVE is positioned between contribution and delivery stages, processing decoded video before final encoding as a pre-compression normalization stage.

By aligning resolution, dynamic range, color space, and temporal stability prior to encoding, it establishes a consistent foundation for downstream compression and distribution. This ensures that quality improvements are preserved through encoding rather than limited by upstream inconsistencies.

3.3 Deployment Flexibility

Pixop LIVE can be deployed at the edge, within production environments, or before distribution, depending on where it provides the most value.

It supports both cloud and on-prem deployments, enabling centralized or distributed processing. Its containerized architecture allows straightforward integration into existing infrastructure without requiring workflow changes.

4. Core Capabilities

Pixop LIVE combines multiple video processing functions into a unified real-time pipeline (see Figure 1), where each stage prepares the signal for final encoding.

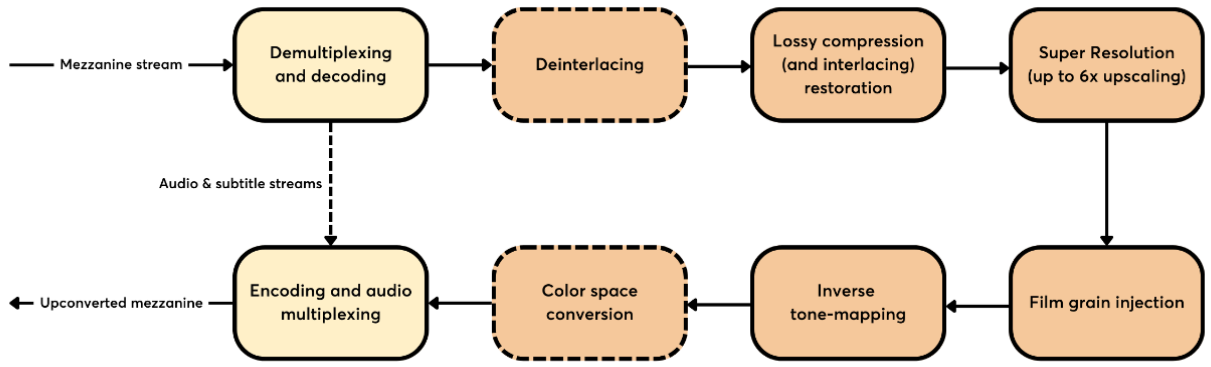


Figure 1 — Pixop LIVE real-time processing pipeline

4.1 Deinterlacing and Format Normalization

Pixop LIVE converts interlaced inputs into stable progressive video for downstream processing.

Rather than treating deinterlacing as an isolated step, it applies learned post-processing to improve conventional deinterlacing output, reducing flicker, edge instability, and line artifacts.

4.2 Restoration and Super-Resolution

Pixop LIVE uses deep learning–based restoration to remove compression artifacts, reduce noise, and recover lost detail.

Super-resolution is then applied to increase spatial resolution and generate additional detail. Multi-frame processing ensures temporal consistency and stable motion.

Separating restoration and super-resolution allows each stage to operate on an optimized input, improving overall quality.

4.3 Artifact Reduction and Temporal Stability

Pixop LIVE maintains temporal stability by reducing flicker, edge instability, and compression-induced artifacts across frames.

Consistent multi-frame processing ensures stable textures and motion, even under aggressive compression or challenging conditions.

4.4 Film Grain and Perceptual Optimization

Pixop LIVE includes adjustable film grain synthesis to preserve a natural visual appearance and avoid overly smooth results.

4.5 SDR to HDR Conversion

Pixop LIVE supports real-time SDR to HDR conversion (PQ and HLG) using analytical inverse tone mapping.

Per-frame analysis adapts the tone mapping curve to expand luminance and color volume while preserving visual intent and avoiding highlight over-expansion.

4.6 Color Space Conversion and Signal Alignment

Pixop LIVE supports color space conversion between Rec. 709 and Rec. 2020.

As part of signal alignment, color representation is adapted to the target format, ensuring consistency and compatibility across workflows.

5. Architecture & Real-Time Performance

Pixop LIVE is a real-time processing system designed for live broadcast environments, combining machine learning-based enhancement with deterministic performance. The architecture is optimized for GPU acceleration, low latency, and predictable behavior under varying workloads.

5.1 Processing Pipeline Overview

Pixop LIVE operates on decoded video frames, applying enhancement stages before re-encoding or downstream delivery.

All compute-intensive processing is performed on the GPU, with frames transferred early into GPU memory to minimize data movement and maximize efficiency. The system can be integrated into existing encoding pipelines or deployed as a standalone processing node, enabling flexible insertion into live workflows without infrastructure changes.

5.2 GPU Acceleration

Pixop LIVE is optimized for NVIDIA GPUs and supports multi-GPU configurations.

Processing is parallelized by dividing frames into segments distributed across GPUs, ensuring high utilization and consistent processing times. The system scales from single-GPU HD deployments to multi-GPU configurations for higher resolutions, with near-linear scaling up to practical limits.

5.3 Latency Profile

Pixop LIVE operates within strict real-time constraints, processing each frame within a fixed time budget.

This is achieved through reduced-precision (FP16) inference, precompiled resolution-specific models, and asynchronous execution. Overlapping computation and data transfer minimizes idle time and maintains high throughput across the pipeline.

5.4 Real-Time Behavior & Synchronization

Pixop LIVE maintains predictable latency under varying input conditions.

The system monitors processing performance and adjusts behavior to remain within the latency budget. When necessary, frames may be dropped and the internal time base resynchronized to prevent latency accumulation, ensuring alignment with the live timeline.

Typical end-to-end latency is approximately 600 milliseconds with

encoding, and lower when encoding is external.

5.5 Stability and Operational Behavior

Pixop LIVE is designed for continuous, stable operation in live environments.

It maintains consistent frame pacing and avoids oscillatory behavior, adapting in real time to variations in input quality, bitrate, and motion complexity. This ensures stable output and timing, even in demanding scenarios such as live sports.

6. Integration & Deployment

Pixop LIVE integrates into professional live media workflows with minimal disruption, supporting both network-based and shared-memory models for flexible, low-latency deployment.

6.1 Workflow Integration

Pixop LIVE operates as a drop-in processing stage between contribution and delivery, enhancing and normalizing video prior to final encoding (see figure 2)

Figure 2 — Pre-delivery encoding integration

It can be deployed at the edge, within production, or before distribution, supporting both centralized and distributed architectures.

6.2 Interfaces and Transport Options

Pixop LIVE supports both IP-based transport and high-performance in-process interfaces.

Network workflows are supported via standard protocols such as MPEG-TS over SRT, while shared-memory integration enables minimal-latency operation in tightly coupled production environments.

In MPEG-TS workflows, Pixop LIVE preserves non-video stream components by passing through audio and data PIDs transparently. This is achieved through a split-and-merge processing approach, ensuring compatibility with existing multiplexed streams without requiring reconfiguration.

6.3 Pre-Integrations

Pixop LIVE integrates with existing broadcast ecosystems without requiring proprietary workflows.

For example, integration with TVU MediaMesh enables shared-memory connectivity for low-latency insertion into live production pipelines. Such integrations reduce deployment friction and allow Pixop LIVE to function as a practical enhancement layer within existing systems.

6.4 Control and Configuration API

Pixop LIVE provides a REST-based API for control, automation, and remote management.

The API supports:

- pipeline lifecycle control (start, pause, stop, status)
- runtime parameter updates and persisted configurations
- job submission and control
- health and service monitoring

Runtime-tunable parameters include controls for tone mapping, film grain, and selected processing features, enabling adjustment without restarting the pipeline where applicable.

6.5 Monitoring and Observability

Pixop LIVE includes built-in monitoring interfaces for operational visibility.

The system exposes:

- Prometheus and JSON metrics
- input/output metadata and thumbnails
- detailed debug telemetry

Available metrics include frame rates, bit rates, latency, dropped frames, GPU utilization, and system state. Additional diagnostics such as queue depths, thread states, and stage-level timing support deeper analysis.

6.6 Job-Based and Daemon Deployment Models

Pixop LIVE supports both direct pipeline control and job-based execution.

In daemon deployments, jobs can be submitted via API for scheduled or orchestrated execution. The system supports distributed execution and stateful job coordination, enabling scalable and resilient processing across multiple nodes.

6.7 Deployment Architecture

Pixop LIVE is delivered as a containerized solution for cloud and on-prem deployment.

It supports Docker-based environments with NVIDIA GPU acceleration and integrates into existing media processing systems without requiring workflow redesign.

7. Technical Specifications

Summary of key technical capabilities for integration and evaluation. Supported configurations may vary depending on deployment and hardware.

7.1 Media Formats & Interfaces

	Input	Output
Protocols / Interfaces	SRT, UDP, TVU shared memory, file-based, pipe (stdin)	SRT, UDP, TVU shared memory, file-based, pipe (stdout)
Containers	MPEG-TS, NUT, raw	MPEG-TS, NUT, raw
Video Codecs	AVC, HEVC, AV1, MPEG-2, XDCAM50, raw	AVC, HEVC, raw
Audio	LPCM, AAC, AC-3, Opus	Passthrough
Data / Ancillary	SCTE-35 and ancillary metadata	Passthrough
Subtitles	DVB, WebVTT	Passthrough

7.2 Video Format Support

	Supported
Input Resolutions	SD, HD, FHD, UHD (4K)
Output Resolutions	720p, 1080p, 2160p
Frame Rates	Up to 60 fps
Scan Types	Interlaced, progressive → progressive
Bit Depth	8-bit, 10-bit
Chroma	4:4:4 / 4:2:2 / 4:2:0
Color Range	Limited, full
Encoder	NVIDIA NVENC
Rate Control	CBR, VBR, CQ
Max Bitrate	Up to 800 Mbps
Typical Live Range	10–50 Mbps (HD/UHD mezzanine)

7.3 HDR & Colorimetry

	Supported
Color Spaces	Rec. 709, Rec. 2020
Transfer	Rec. 709, Rec. 2020-10, PQ (HDR), HLG (HDR)
Conversion	SDR → HDR (real-time)
Color Conversion	Rec. 709 ↔ Rec. 2020

7.4 Core Processing

	Description
Deinterlacing PP	Learned post-processing of deinterlaced video
Restoration	Artifact removal, noise reduction, detail recovery
Super-Resolution	Upscaling with temporal consistency
Temporal Stabilization	Flicker and motion stabilization
Film Grain	Adjustable perceptual grain synthesis
HDR Conversion	Analytical inverse tone mapping
Color Alignment	Signal normalization to target format

7.5 Performance

	Typical
Throughput	Up to 60 fps
Latency (E2E)	~600 ms (with encoding)
Low-Latency Mode	<100 ms (shared memory)
Latency Control	Frame dropping + resync

7.6 GPU Scaling

	Capability
HD	1 × NVIDIA RTX PRO 6000 (Blackwell-class) GPU
4K	2 × NVIDIA RTX PRO 6000 (Blackwell-class) GPUs
Scaling	1–8 GPUs supported
Parallelization	Frame segmentation across GPUs

7.7 Control & Monitoring

	Supported
Control	Start, pause, stop, status
Parameters	Runtime + persisted
Monitoring	Prometheus, JSON, OpenTelemetry
Logging	ANSI (human-readable), structured JSON
Diagnostics	Debug telemetry, pipeline metrics
Visual	Input/output thumbnails
Jobs	Submit, list, stop
Auth	Basic, bearer
Quality Metrics	No-reference MOS (input/output)

7.8 Deployment

	Requirement
CPU	64-bit x86 (typically low utilization, GPU-bound)
Memory	≥32 GB
GPU	NVIDIA CUDA
OS	Linux
Container	Docker
Runtime	NVIDIA Container Toolkit
Deployment	Cloud or on-prem

8. Reliability & Operational Confidence

Pixop LIVE is designed for continuous operation in live broadcast environments, where stability, predictability, and observability are critical. The system maintains consistent performance under varying input conditions, network behavior, and processing load.

8.1 Deterministic Real-Time Operation

Pixop LIVE operates within a fixed latency budget, maintaining alignment with the live timeline.

Processing is continuously monitored and adjusted to prevent latency accumulation. When required, frames may be dropped and the internal time base resynchronized, ensuring stable timing under varying conditions.

Pixop LIVE is designed for continuous operation over extended live events, maintaining stable timing behavior over hours of uninterrupted processing. The system prevents latency drift by actively managing processing budgets and resynchronizing when required, ensuring alignment with the live timeline throughout the duration of the event.

8.2 Robust Handling of Input Variability

Pixop LIVE supports a wide range of input conditions, including compressed feeds, interlaced formats, and varying motion or lighting.

The pipeline adapts in real time, maintaining consistent output quality without manual intervention.

8.3 Error Handling and Resilience

Pixop LIVE is designed for robust operation in live environments.

Input integrity is monitored, and corrupted or incomplete frames are handled gracefully. Under constrained conditions,

the system prioritizes timing stability and continuity over uncontrolled latency growth.

When encountering degraded input conditions, transient decode issues, or processing overload, Pixop LIVE prioritizes continuity of output. Frames may be dropped and the internal time base adjusted to prevent latency accumulation, ensuring that the output remains synchronized rather than delayed.

Typical failure modes include input instability, bitrate fluctuations, or sudden increases in motion complexity. In these scenarios, the system adapts dynamically to maintain real-time operation without requiring manual intervention.

8.4 Observability and Diagnostics

Pixop LIVE provides comprehensive observability through built-in monitoring interfaces (see figure 3).

Telemetry includes frame rates, latency, dropped frames, GPU utilization, and system state. Detailed diagnostics such as stage-level timing, queue depths, and thread activity support troubleshooting and optimization.

8.5 Operational Control Interface

Pixop LIVE includes a web-based control interface for real-time monitoring and system control (see figure 4).

The interface provides visibility into pipeline performance, GPU utilization, latency, and processing state, and enables runtime adjustment of key parameters. This allows operators to monitor, validate, and adjust the system during live operation without direct infrastructure access.

In addition to routine monitoring, the system supports controlled operational intervention. Operators can adjust processing behavior in response to changing input conditions, and perform controlled state transitions such as pause and restart when required. This ensures predictable system behavior and recovery during long-running live events without disrupting downstream workflows.

Figure 3 — A Grafana dashboard based on data from the Prometheus metrics endpoint

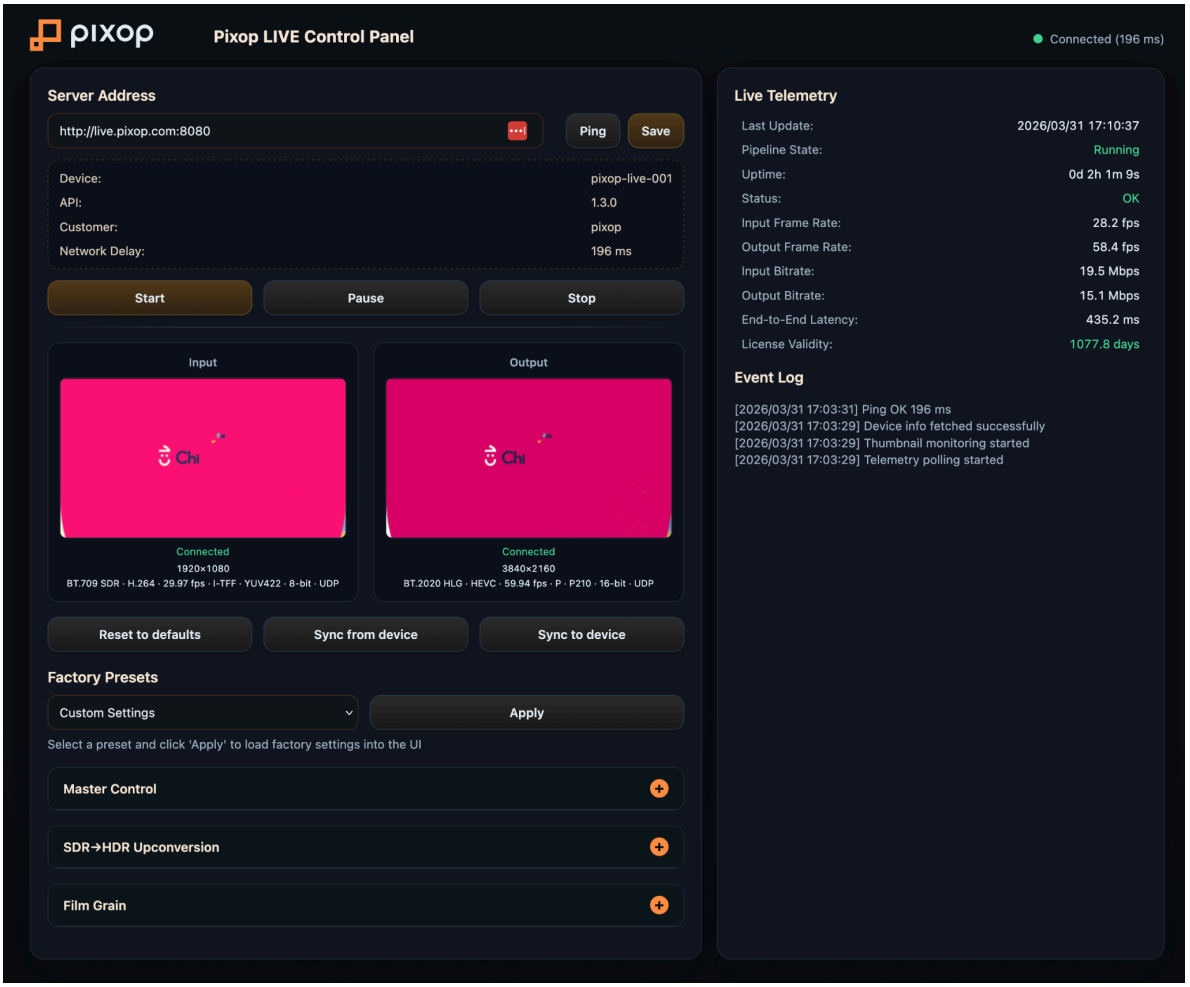


Figure 4 — Pixop LIVE web-based control interface with real-time monitoring and control

8.6 Perceptual Quality Monitoring (MOS Estimation)

Pixop LIVE includes a no-reference video quality assessment model that estimates perceptual quality using Mean Opinion Score (MOS).

MOS is computed for both input and output streams, with output converted to SDR for consistent evaluation. This enables direct comparison of perceptual quality before and after processing.

MOS supports real-time monitoring, deployment validation, and ongoing quality assurance, providing a quantitative measure of enhancement impact.

9. Use Cases

Pixop LIVE enhances video quality across a range of live broadcast and streaming workflows, balancing quality, consistency, and latency.

9.1 Live Sports Production

Live sports presents highly compressed feeds, fast motion, and complex textures.

Pixop LIVE improves clarity by restoring detail, stabilizing motion, and reducing artifacts, resulting in:

- clearer player outlines and jersey details
- more stable pitch textures and markings
- reduced flicker in fine patterns and LED boards

It operates within live latency constraints, making it suitable for both primary and distribution feeds.

Figure 5 illustrates a representative SDI-to-OTT integration scenario, showing how Pixop LIVE can be deployed between contribution ingest and delivery encoding within a live sports workflow.

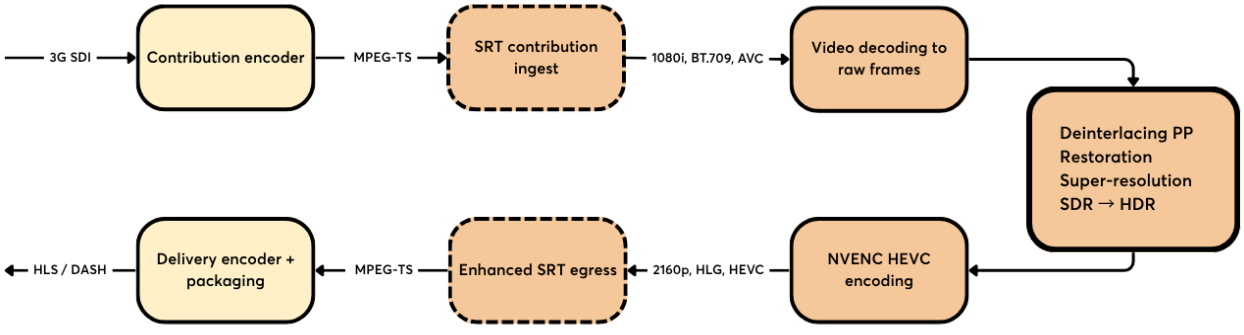
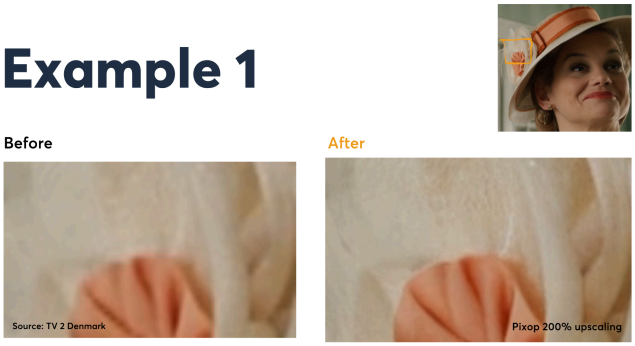


Figure 5 — Example live sports workflow with Pixop LIVE integration (SDI to HLS)

9.2 UHD and HDR Channel Upgrade

Pixop LIVE enables real-time upconversion from HD SDR to 4K HDR, allowing channel upgrades without replacing existing production infrastructure (see example 1).

This supports gradual migration to UHD and HDR while maintaining compatibility with current workflows.

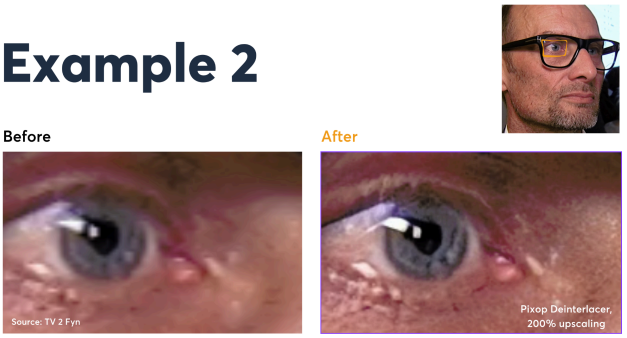


9.3 News and Broadcast Production

News workflows combine diverse sources with varying formats and quality.

Pixop LIVE normalizes these inputs (see example 2) into a consistent output, improving continuity across:

- mixed SD, HD, and interlaced content
- remote reporting feeds
- legacy footage in live broadcasts



9.4 Remote Production and Contribution

In bandwidth-constrained environments, Pixop LIVE enhances compressed contribution feeds before further processing or distribution.

It can be deployed at the edge or centrally, improving signal quality in cloud-based and distributed production workflows.

9.5 Mezzanine and Distribution Enhancement

Pixop LIVE can be deployed prior to final encoding to improve mezzanine feeds.

By aligning resolution, dynamic range, and color before compression, it improves both visual quality and compression efficiency across OTT, partner distribution, and channel playout workflows.

10. Conclusion & Next Steps

Pixop LIVE introduces a structured approach to real-time video enhancement by establishing a pre-compression normalization stage within the live workflow. By consolidating restoration, super-resolution, tone mapping, and color alignment into a unified pipeline, it delivers consistent visual quality across a wide range of input conditions.

The system is designed for professional live environments, balancing visual improvement with deterministic latency and operational stability. Its flexible deployment model allows integration at multiple points in the pipeline without requiring changes to existing infrastructure.

This enables broadcasters, content providers, and platform operators to improve output quality, extend the value of existing assets, and align with modern delivery standards such as UHD and HDR.

Beyond technical quality improvements, this approach enables greater consistency in visual presentation across channels and programs. By stabilizing and aligning the signal prior to encoding, broadcasters can maintain a more coherent and recognizable visual identity, even when source material varies significantly in quality or format.

Pixop LIVE is currently being evaluated and deployed across live production and distribution workflows. Organizations can validate the system using real-world feeds and operational scenarios.