Essentials of DisplayPort Display Stream Compression (DSC) Protocols

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Webinar – February – 2018

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Agenda

- DisplayPort Protocols Review
- Display Stream Compression (DSC) Overview
- Visually Lossless Compression Principles
- How does DSC work?
- DisplayPort DSC Protocol Operation

- Please Check out our other “Essentials of” Webinars:
  - Essentials of DisplayPort Protocols
  - Essentials of HDCP 2.2 Protocols
  - Essentials of HDMI Fixed Rate Link (FRL) Protocols
  - Essentials of DisplayPort Display Stream (DSC) Protocols

Please feel free to contact me, Neal Kendall at:
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If you have any questions.

DisplayPort Protocols Review

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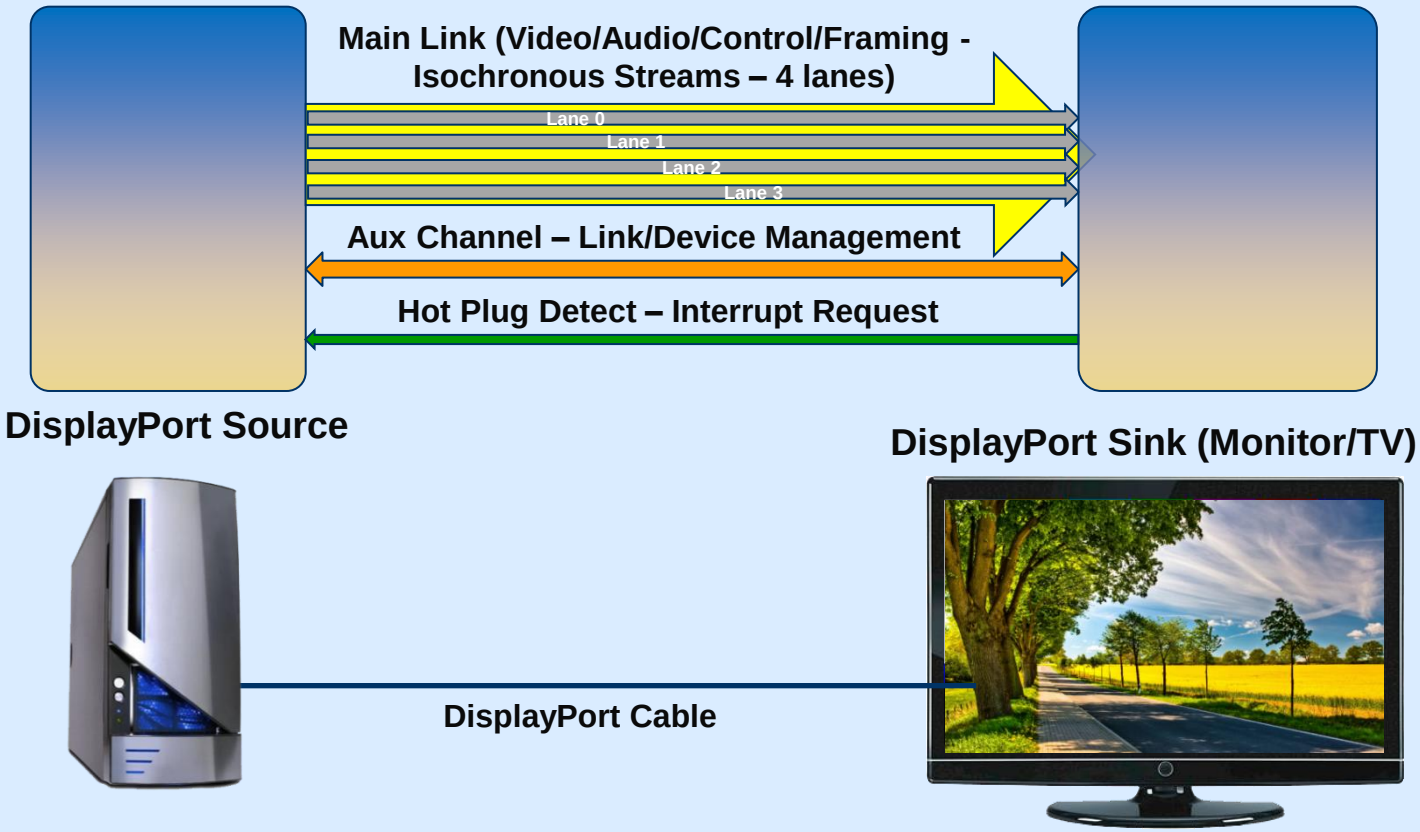
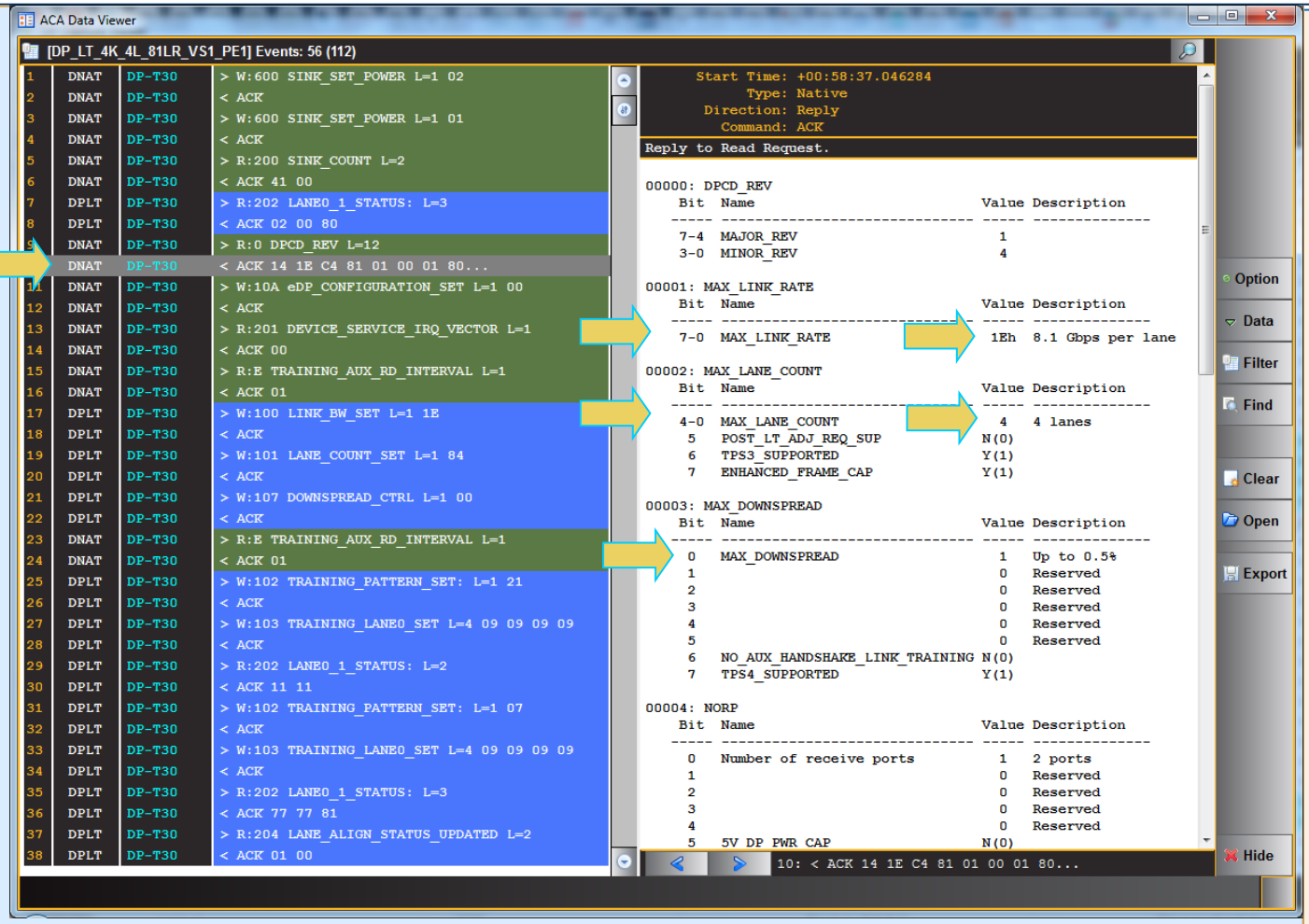
DisplayPort Anatomy



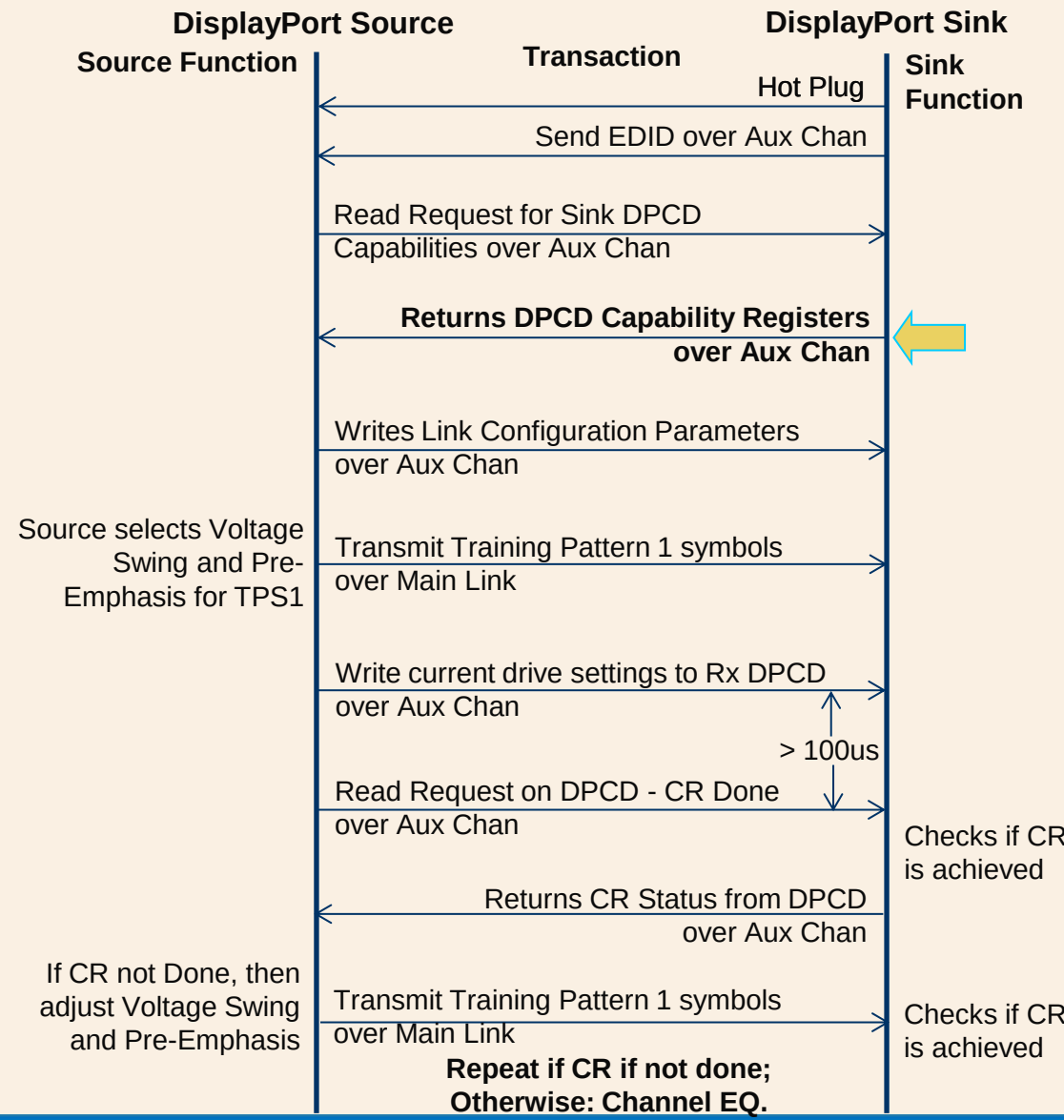
- Main Link: Unidirectional, high-bandwidth channel used to transport video, audio and metadata and protocol control elements.
- Main Link 1, 2 or 4 Lane Configurations.
- Main Link 4 link rates:
  - 1.62Gbps (Reduced Bit Rate)
  - 2.7Gbps (High Bit Rate)
  - 5.4Gbps (High Bit Rate 2)
  - 8.1Gbps (High Bit Rate 3)
- No clock channel. Sink recovers clock using link transitions.
- Aux Channel: Bidirectional, half duplex channel with a data rate of 1Mbps. Link Training, DSC Configuration, DPCD Register status, HDCP authentication & EDID.
- Hot plug:
  - Connection Detection.
  - Interrupt mechanism in cases where there is a failure in the link.

DisplayPort DSC Protocol Review
Aux Channel Link Training

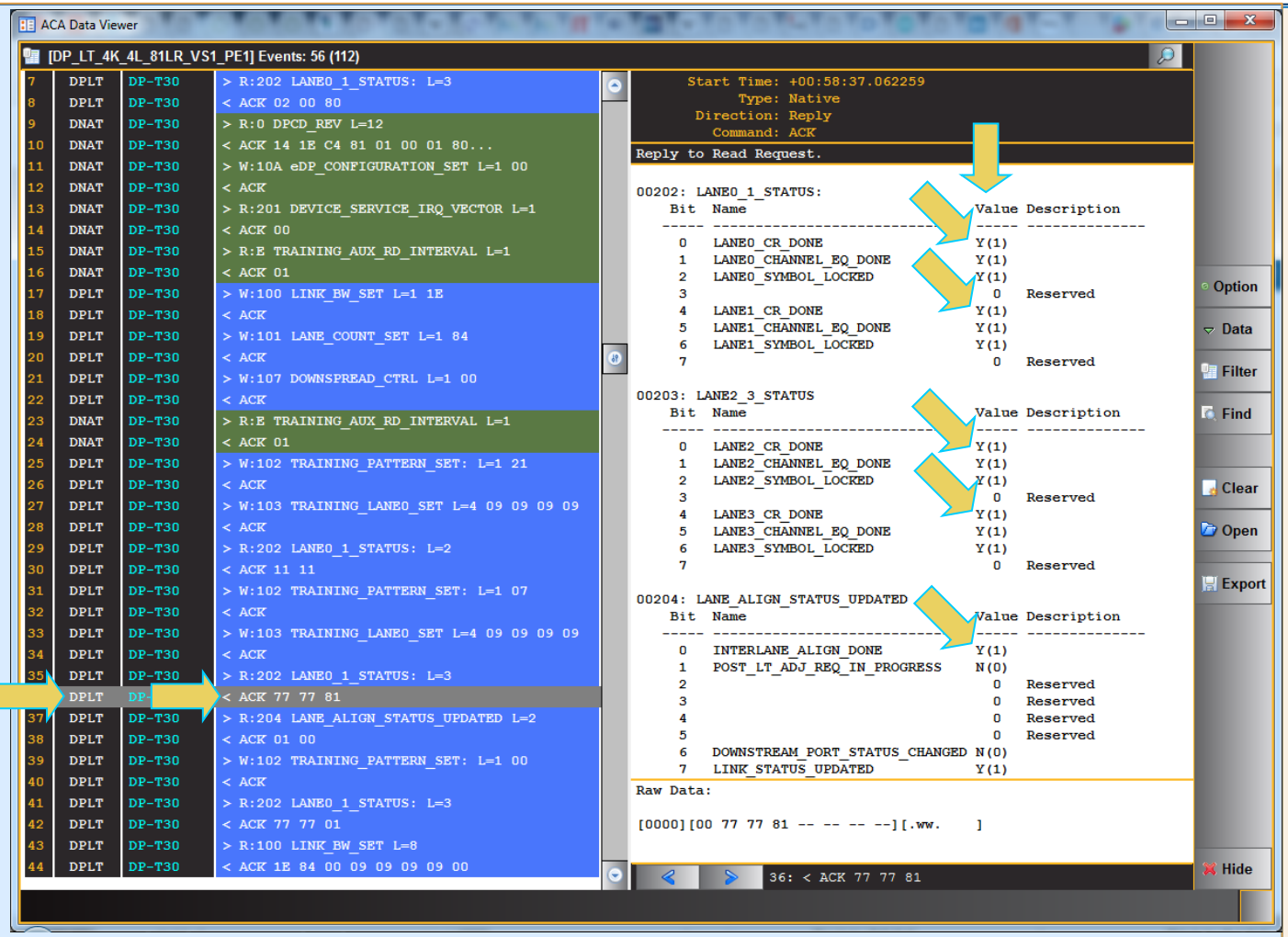
DisplayPort – Link Training Sequence



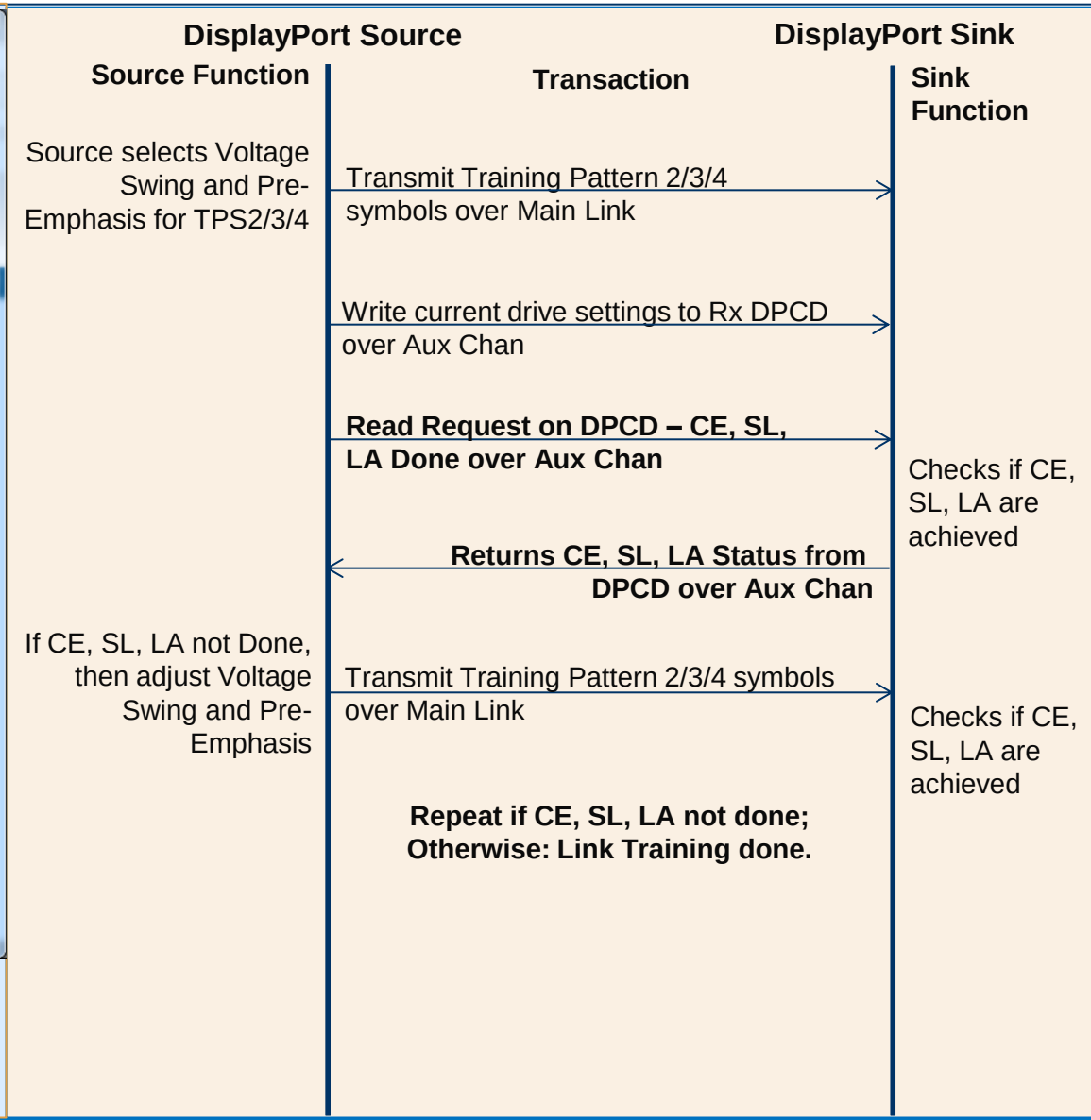
Source Reading Sink DPCD Capability Registers



Connection Sequence – Link Training Channel EQ, Symbol Lock, Interlane Alignment

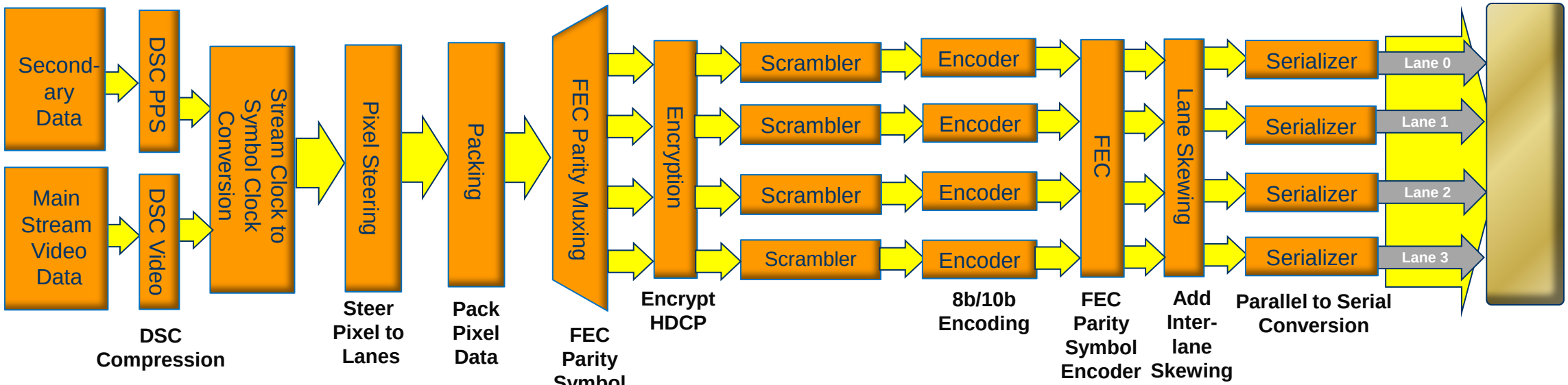


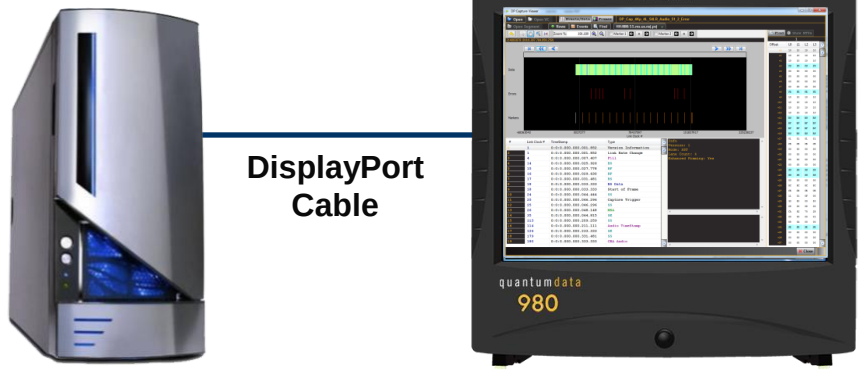
Source Reads Status of Channel Equalization, Symbol Lock and Inter-Lane Alignment Link Training All Done!



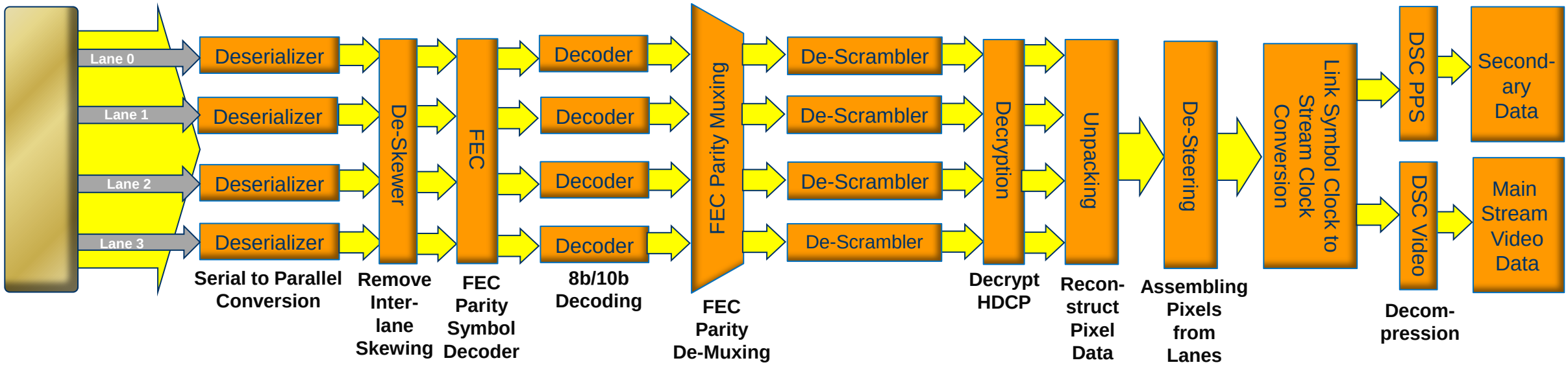
DisplayPort Protocol Review
Main Stream

DisplayPort Main Link Stream Generation in Source (Transmitter)



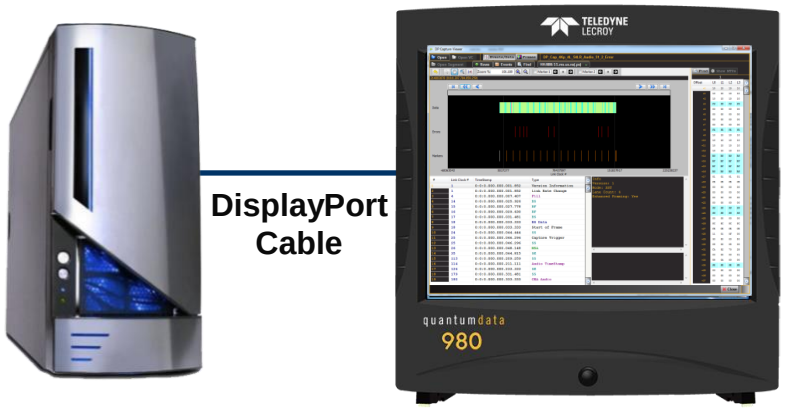


DisplayPort Main Link Stream Generation in Sink (Receiver)



DisplayPort Source

DisplayPort Receiver



DisplayPort Main Link Protocol – One Video Frame

- Video packets occur during the active video period.
- Metadata: Main Stream Attributes (MSA) and Secondary Data Packets (SDP) occur during the vertical blanking period and are identified with Framing control characters.
- Fill characters are zeros for filling up (stuffing) the unused link symbols.

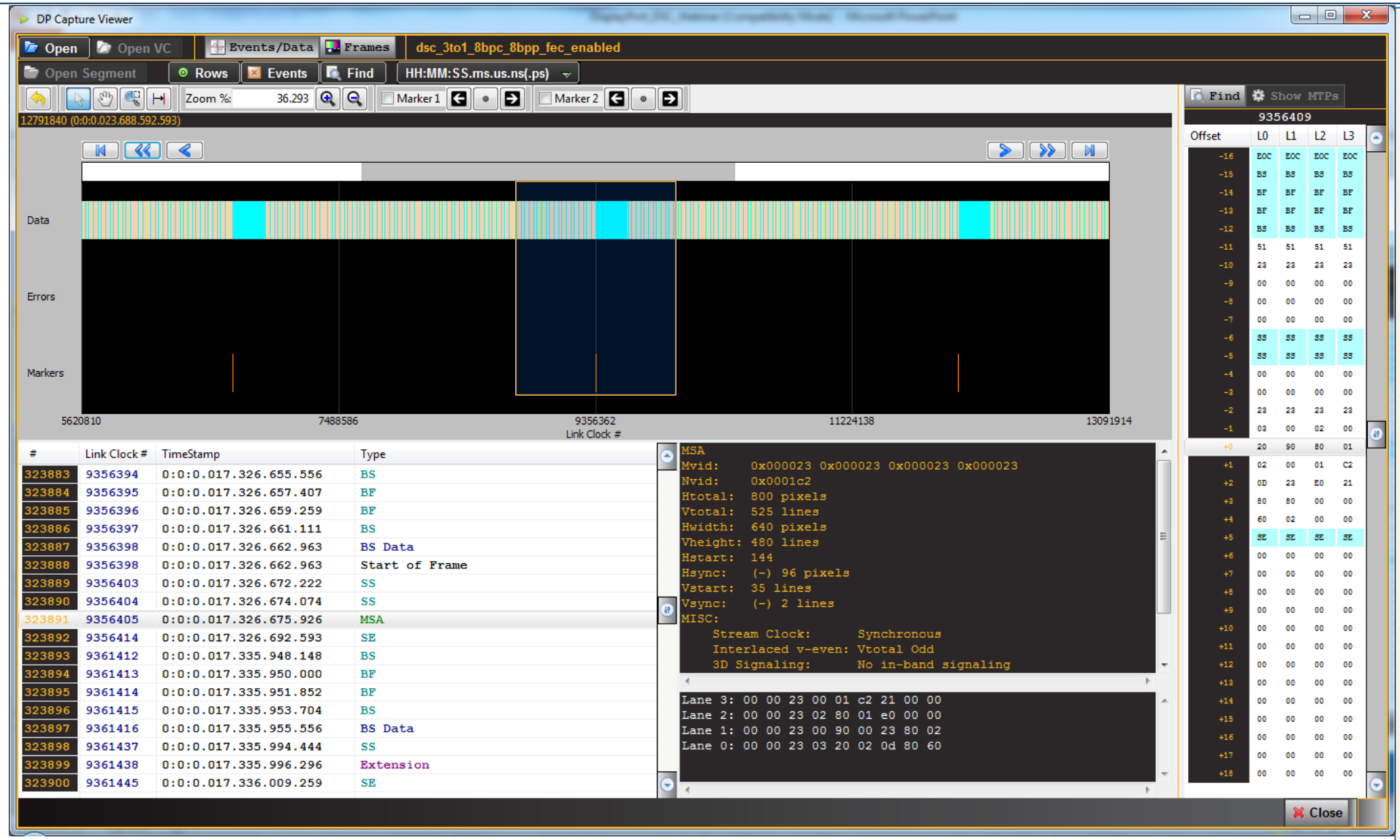
Video **Fill Characters**

Metadata **Control Symbols**

Audio **Control VBID w/ Compression Flag Set**

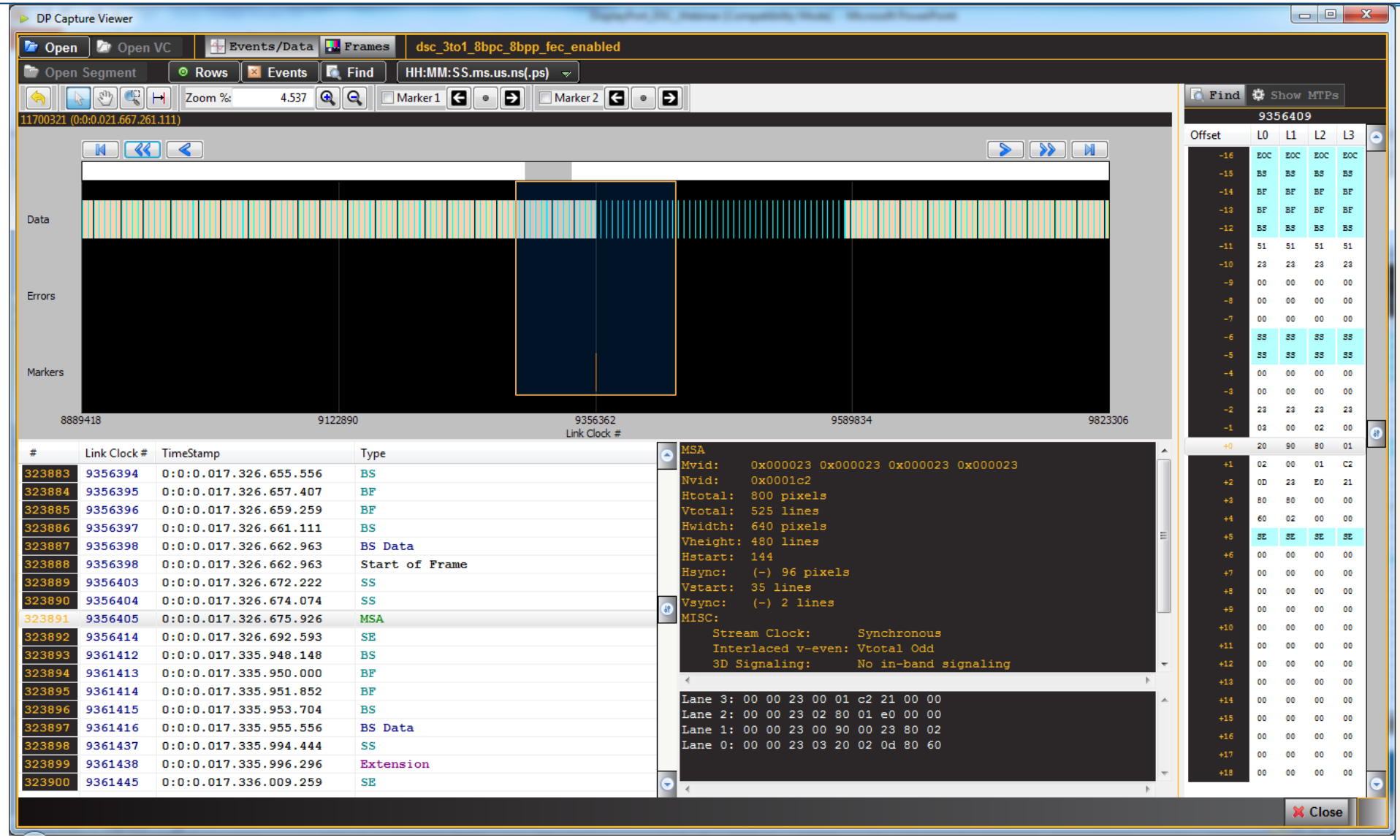
PPS **EoC**

DisplayPort Main Link Protocols – Protocol Capture



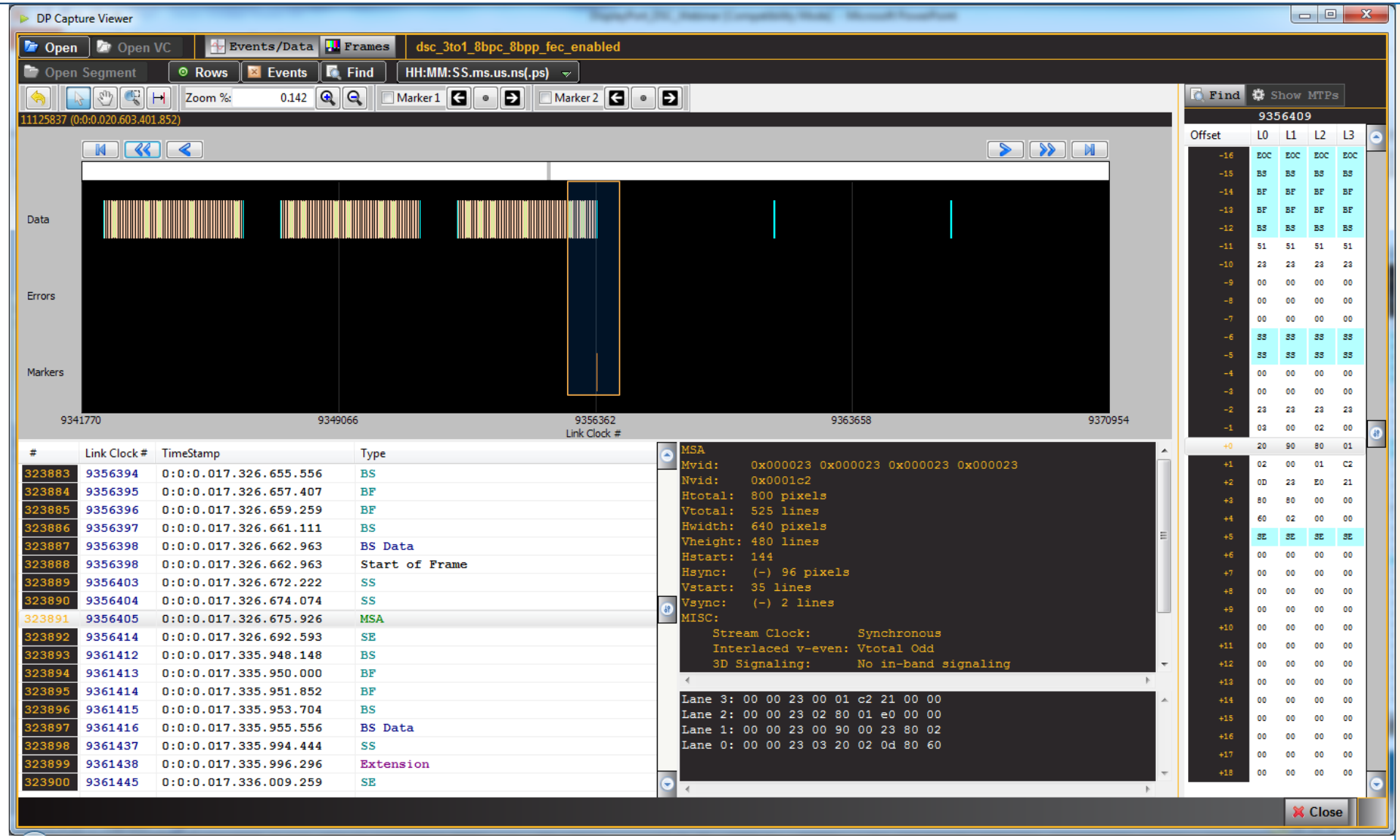
- Zoomed out view.
  - Showing multiple frames (vertical blanking in blue).

DisplayPort Main Link Protocols – Protocol Capture



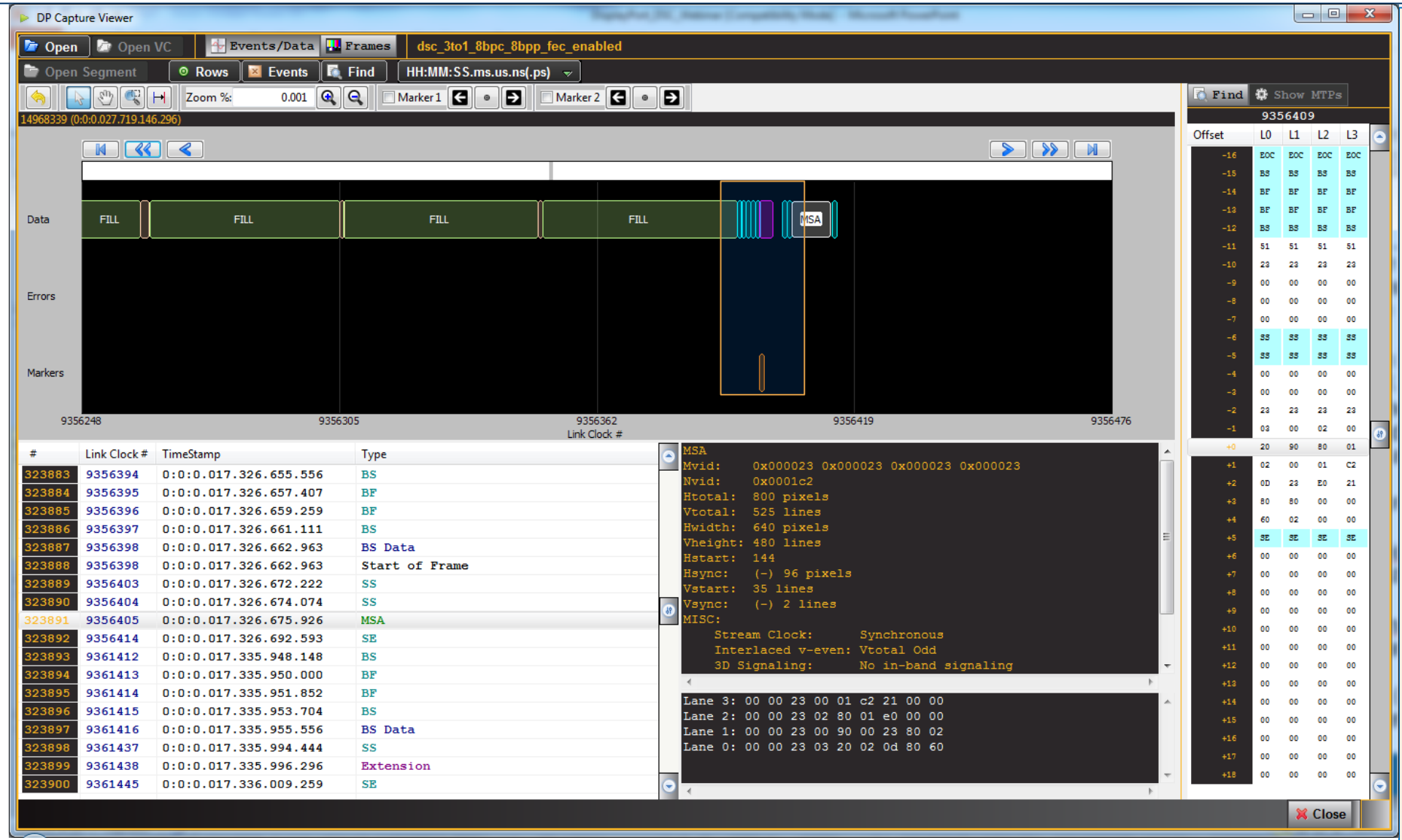
- Zoomed in view.
  - Showing one video blanking frame.
  - Showing multiple lines of video data.

DisplayPort Main Link Protocols – Protocol Capture



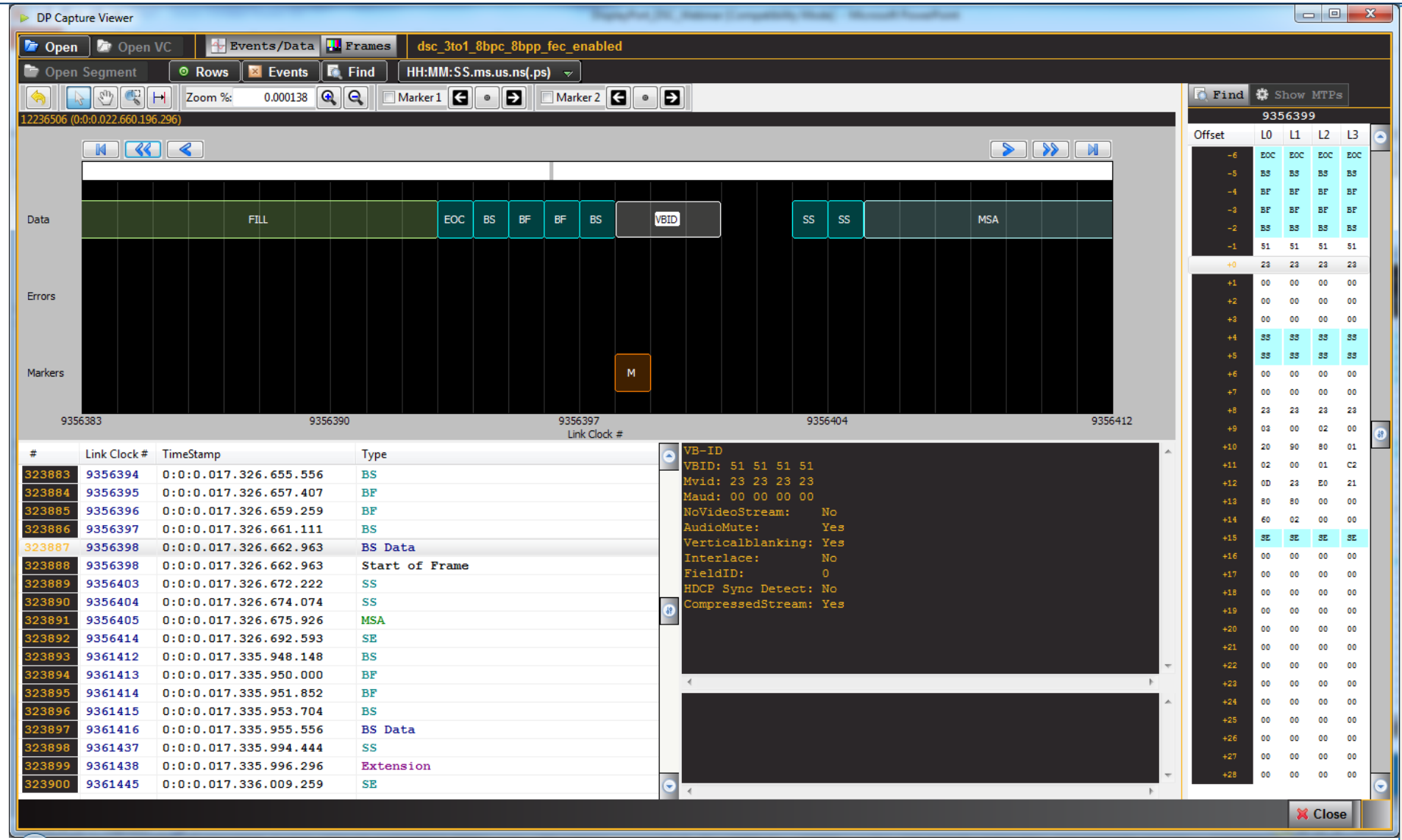
- Zoomed in view.
  - Showing three video lines of data.
  - Showing two horizontal blanking periods.
  - Shows part of one vertical blanking period with secondary data packets (slivers in blue).

DisplayPort Main Link Protocols – Protocol Capture



- Zoomed in view.
  - Showing vertical blanking period with secondary data packets (MSA).
  - Showing three video transfer units (video and blanking).

DisplayPort Main Link Protocols – Protocol Capture



- Zoomed in view.
  - Showing beginning of one vertical blanking period.
  - Shows some DSC elements (end of chunk).
  - Shows vertical blanking secondary data packets (VB-ID) with compression flag set.

DisplayPort DSC Overview

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Origins of Display Stream Compression (DSC)

- How did DSC come about?
  - Higher resolution content sources and displays led to a need for greater bandwidth over the display link.
  - Display links carry multiple high resolution streams, e.g. DisplayPort Multi-Stream Transport.
  - Cable transmission limitations at high resolutions for video formats.
  - Need for reduced power consumption in mobiles.
- An industry standard was needed to address this issue; proprietary solutions result in interoperability problems.
  - In 2012 VESA formed the Display Stream Compression (DSC) task group.
  - VESA in association with MIPI Alliance developed the Display Stream Compression (DSC) standard.
- VESA Display Stream Compression (DSC) requirements:
  - Visually lossless light compression with 2:1 to 3:1 compression ratios.
  - Real time encoding and decoding with very low latency for gaming and interactive use cases.
  - Support for RGB and YCbCr at 4:4:4, 4:2:2 & 4:2:0 chroma subsampling.
  - Bit depths of 8, 10, 12, & 16 needed to be supported.
  - Support partitioning of the compressed frame to limit extent of compression artifacts in the case of bit errors over the link.
- Existing video compression standards such as MPEG-2, H.264, JPEG-2000 do not meet these requirements.

Why Display Stream Compression (DSC)?

- Why is DSC used in DisplayPort?
  - The new compression standard needed to be visually lossless as the content itself is often encoded with a lossy compression such as MPEG.
  - DisplayPort features require very high bandwidth over the display link interface.
    - Very high resolutions (4K@60/120Hz and 8K@60Hz) and corresponding data rates 8.1Gb/s over a pair (lane). DSC allows lower link rates to transmit a high video resolution.
    - Multi-stream transport (MST) requires more bandwidth.
  - Support for DisplayPort over USB-C interface.
    - USB-C DP Alt mode often uses only two (2) DisplayPort lanes for transmission.

Notes:

Note 1: Forward Error Correction (FEC) is required to be used with DSC in DisplayPort.
However this webinar will not be discussing FEC.

Note 2: DSC is supported in the Multi-Stream Transport (MST) mode.
However, this webinar will not be discussing DSC with MST.

Visually Lossless Compression Principles

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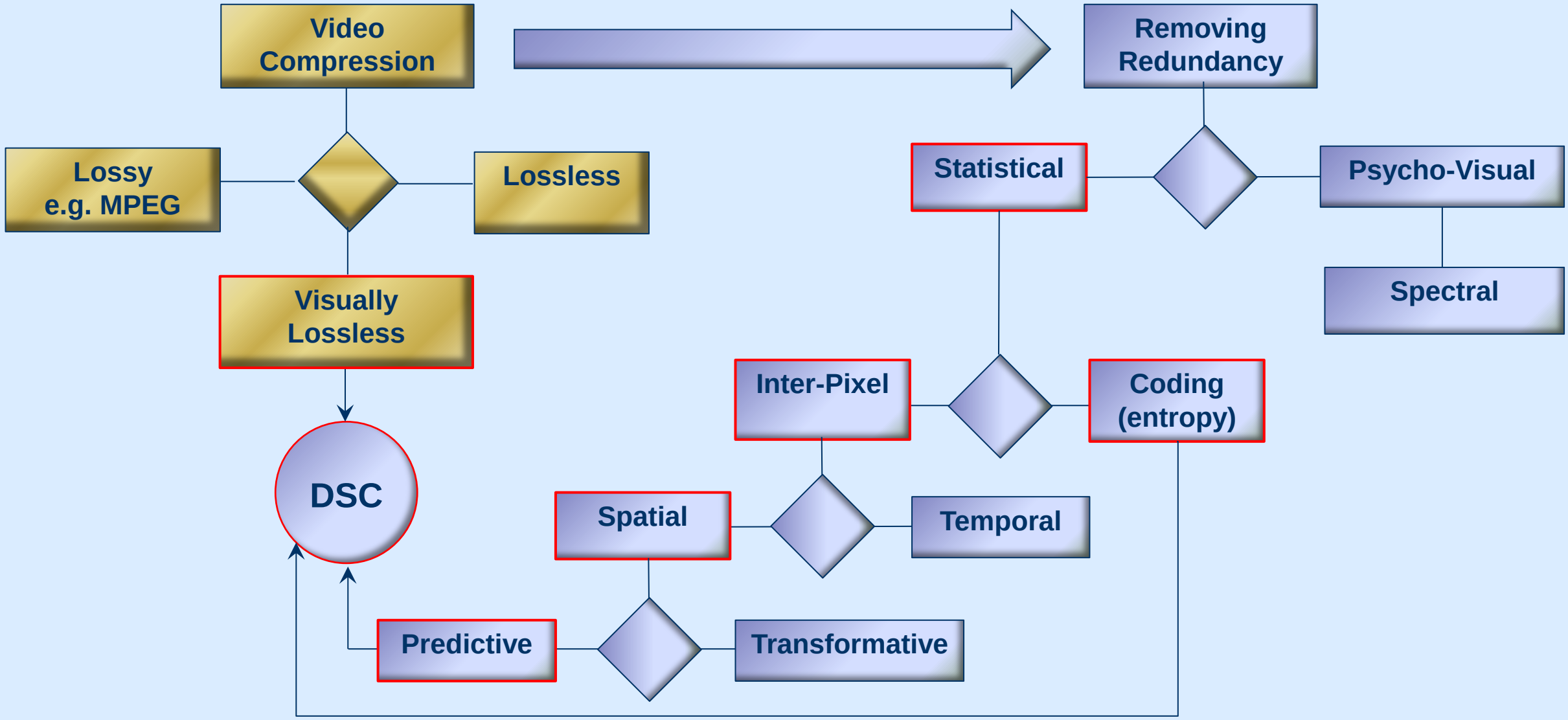
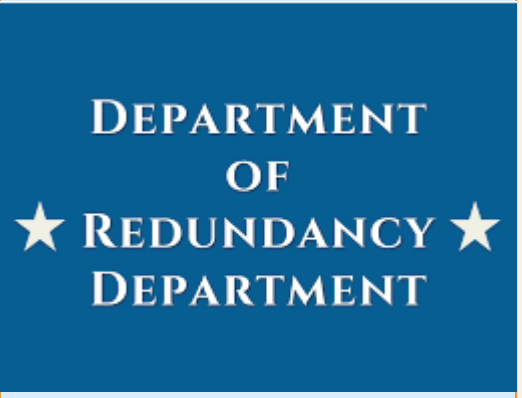
Video Compression Principles – Video Compression Taxonomy



Video Compression Principles – Categories of Compression

- Categories of Compression – Quick Facts.
- Video compression is about **removing redundancy** in video transmission.
- There are **three (3) broad categories of compression in terms of the visual effectiveness**:
  - Lossy compression such as MPEG and H.264 – Standard lossy image compression algorithms strive for “good enough.” They are irreversible. They exploit the fact that human visual system is unable to detect some spectral components.
  - **Visually lossless** compression – Redundancy is removed but **subjective tests show no appreciable loss**.
  - Lossless compression – The image after decompression is identical to the original. The process is reversible.

Video Compression Principles – Types of Redundancy



- Types of Redundancy – Quick Facts
- Video compression is about removing redundancy in video transmission.
- Redundancy occurs when there is **more data than is necessary** to carry a certain amount of information.
- There are two (2) broad categories of redundancy in images:
  - Psycho visual redundancy.
  - **Statistical Redundancy** which can be classified into:
    - **Inter-pixel** redundancy.
    - Coding redundancy.
- Inter-pixel redundancy can be classified into:
  - Spatial redundancy (used in DSC).
    - **Redundancy within video frames**. A pixel position within a frame is same (or similar) as its neighboring pixels.
  - Temporal redundancy.
    - Redundancy between video frames. A pixel position in two frames has the same (or similar) value.
- There is also Spectral redundancy involving color. It is a form of psychovisual redundancy. It relates to the limitations of the acuity of the human visual.
  - RGB vs YCbCr with 4:2:2 chroma subsampling is a way of removing spectral redundancy. This exploits the fact that human visual system is much more sensitive to luminance than chrominance.

Video Compression Principles – Prediction to Remove Redundancy

- Prediction Methods – Quick Facts.
- Temporal vs Spatial prediction.
  - Temporal prediction works between frames. It is better than spatial prediction in static areas where little motion has occurred between frames.
  - **Spatial prediction** works **within a frame**. It is better than temporal prediction with high motion areas because they have less pixel correlation with corresponding areas in previous frames.
  - Spatial redundancy is what is reduced in **Display Stream Compression (DSC).**
- Image compression algorithms that work by removing spatial redundancy can be divided in two main categories according to the method that is used:
  - **Prediction-based** techniques use a simple assumption that **adjacent pixels are highly correlated**. A current pixel value can be predicted reasonably well based on neighboring pixel values.
  - Transformation-based techniques transform data in such way that allows better exploitation of spectral components that are present on image.
  - **DSC uses Prediction-based** techniques.

How Does DSC Work?

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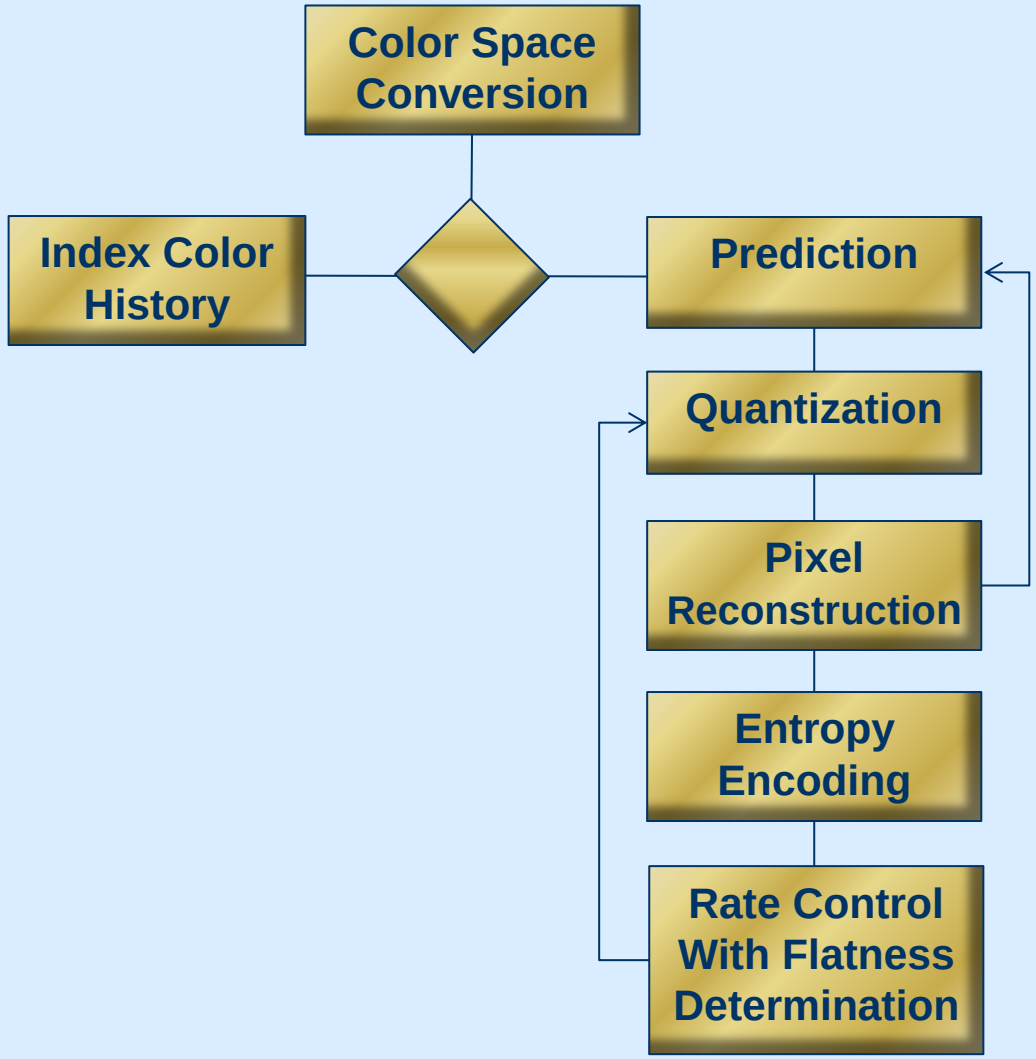
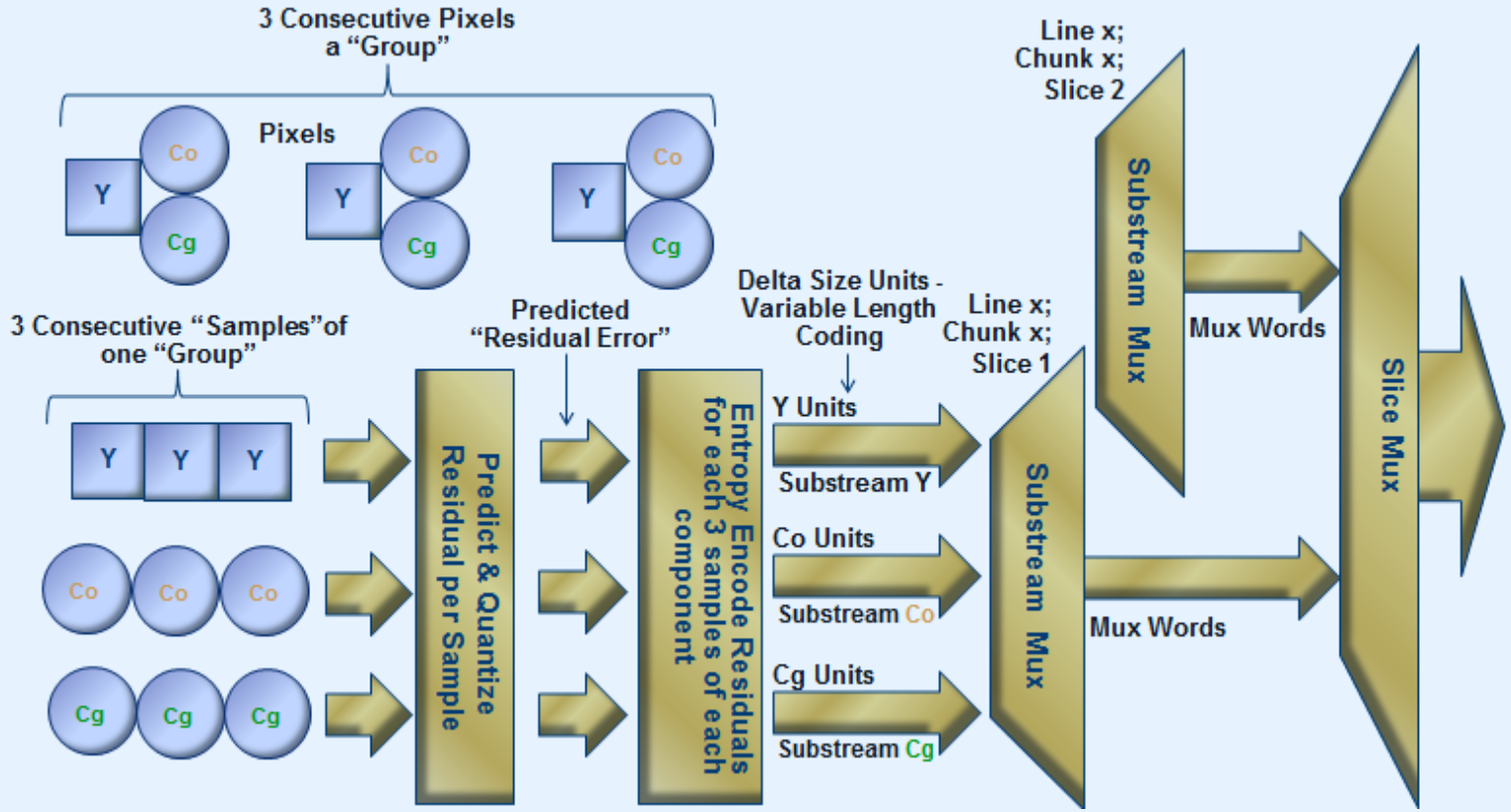
Display Stream Compression – How Does DSC Compression Work?



- Display Stream Compression – How it Works:
  1. Color Space Conversion – RGB inputs are converted to YCoCg-R.
  2. Prediction – One of three (3) models: 1) Median-Adaptive, 2) Block, 3) Midpoint.
  3. Indexed Color History – An alternative to Prediction where recently used pixel values are stored and available to be referenced.
  4. Quantization – Assigns bit values to a residual sample produces some level of error, i.e. lossy component.
  5. Pixel Reconstruction – Recreating the pixels in the encoder using the same method used in the decoder.
  6. Entropy Encoding – A way of encoding values such that the more frequently occurring values are encoded with fewer bits than less frequently occurring values.
  7. Rate Control – Process to ensure proper bitstream flow. Manages buffer fullness to ensure that it is not underflowed or overflowed. Controls quantization in association to flatness.
  8. Flatness determination – Flatness is the constancy of pixel values or “smoothness” in an area of the video.

Display Stream Compression – Terminology

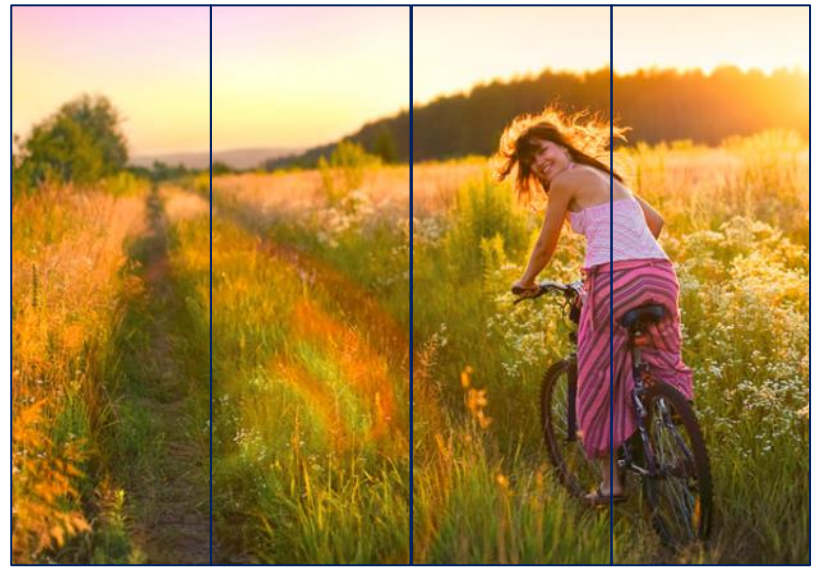


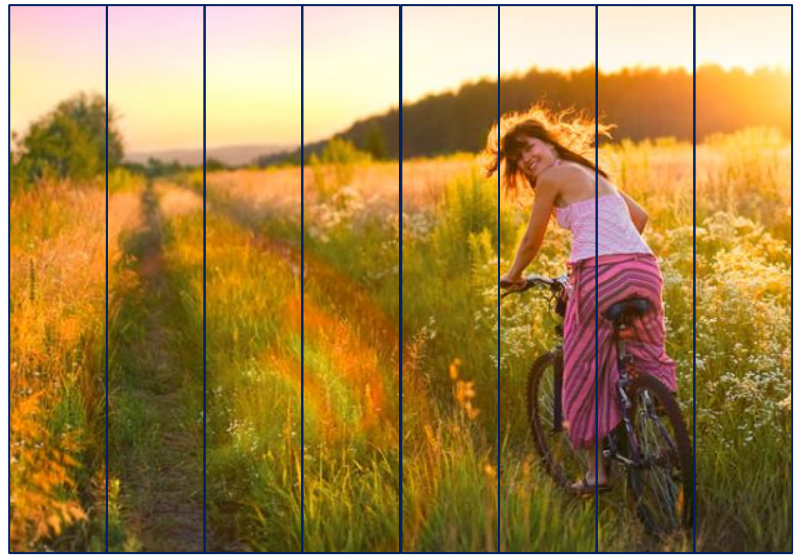
- Important DSC Terminology
  - **Pixel** – A single controllable distinct visual element on a video frame.
  - **Sample** – One component of one pixel. A distinct component value within a pixel Unit, e.g. Y, Co, Cg.
  - **Group** – A logical element set composed of three (3) consecutive pixels (in raster scan order) in a line on a video "Picture".
  - **Unit "Delta-sized Units" –** A variable length encoded element of the prediction based residual representing a single Sample's (component) within a group.
  - **Substream** – A stream of component bits for one component, i.e. from one Unit.
  - **Substream Mux** – Multiplexes multiple component substreams in to "Mux Words."
  - **Slice** – A rectangular partition of a video "Picture" that's encoded/decoded independently of other slices within the Picture. All slices within a Picture are the same size.
  - **Slice Mux** – Used when there are multiple slices per line (which is most of the time). Chunks for each line are muxed together.
  - **Chunk** – Portion of encoded bitstream that comprises a line of compressed video.

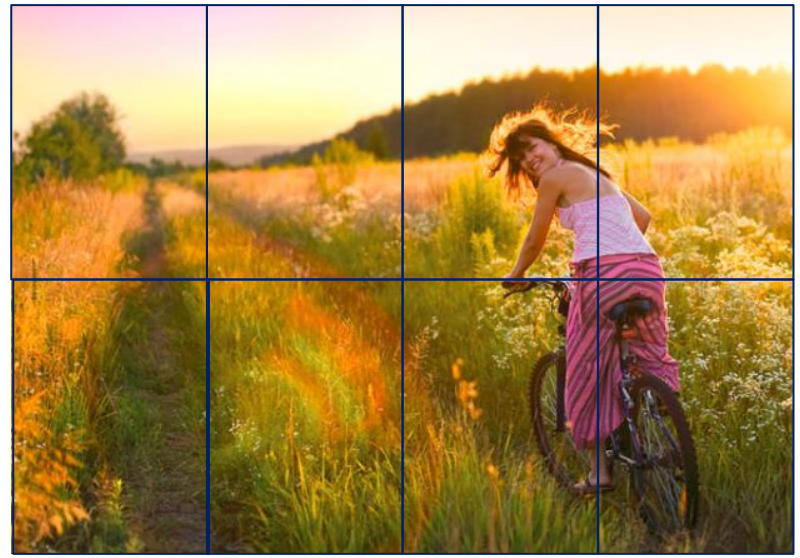
Display Stream Compression – Slices

- DSC Slices – Quick Facts.
  - A slice is a rectangular partition of a video frame.
  - Each slice is **encoded independently** of other slices within the frame.
  - There can be one or multiple slices per line.
  - When there are multiple slices per line, the “Slice Multiplexing” function is used to multiplex the slice data into the bit stream.
  - All **slices within a frame are the same size**.
  - Taller slices offer better compression.
  - **Slice configuration** is **transmitted** from a source encoder to a sink decoder in **metadata (Picture Parameter Set [PPS])**.
- Why use slices…why partition the video frame?
  - Partitioning the video into slices to ensure transmission **errors aren’t propagated** across the slices.
  - Slice partitioning allows or facilitates parallel processing of slices.

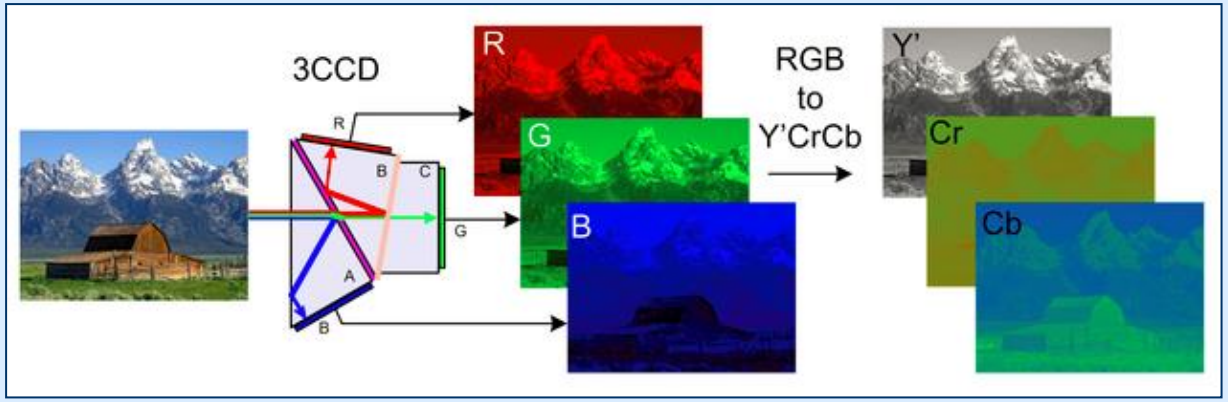
Display Stream Compression – Slice Configurations

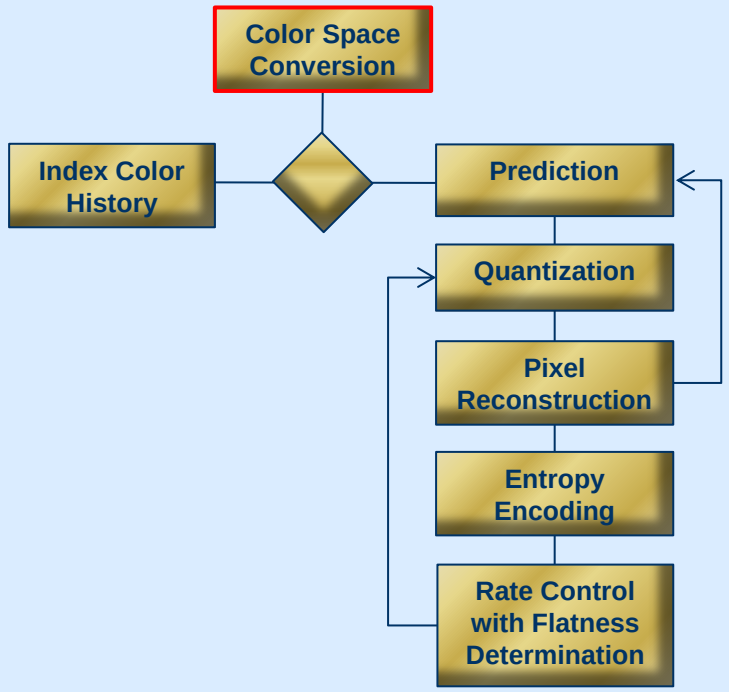






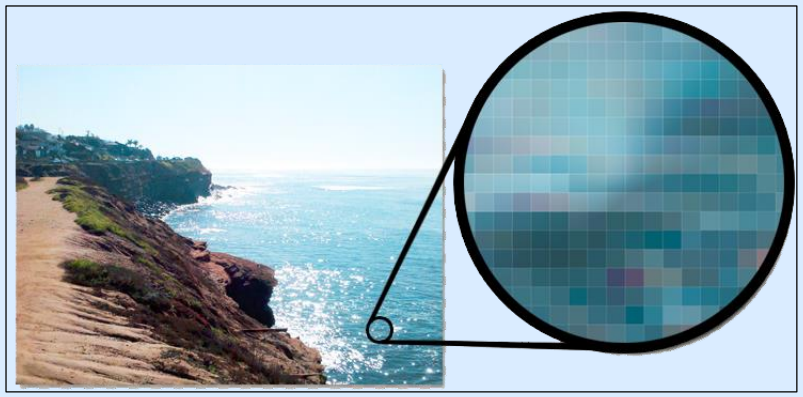
Display Stream Compression – Color Space Conversion

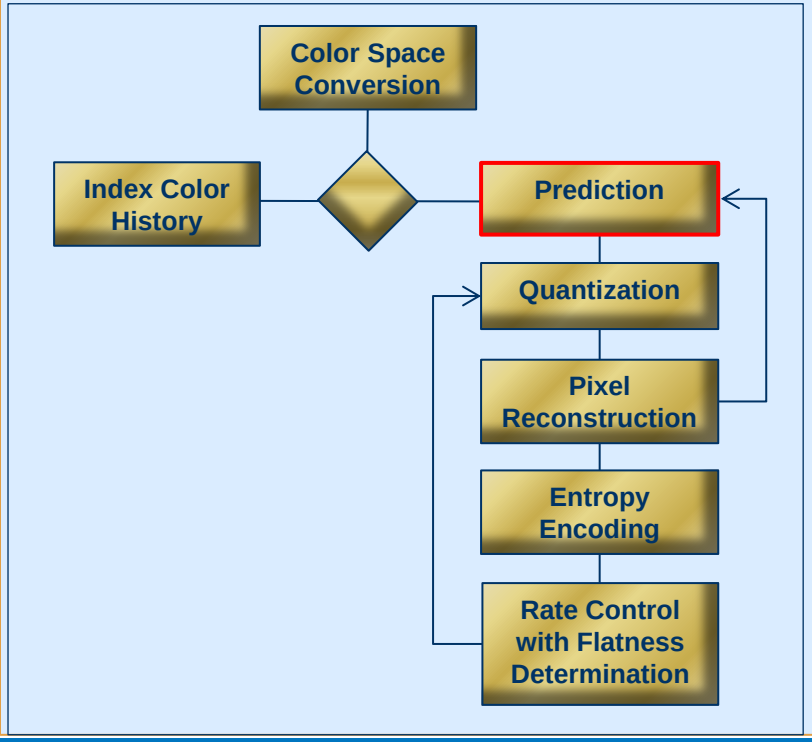




- Color Space conversion – Quick Facts
  - DSC uses only component color encoding of Y (luminance), Co (Chrominance Orange), Cg Chrominance Green).
  - If the video is RGB then the first step in the DSC encoding is color space conversion.
  - Color Space Conversion – RGB inputs are converted to YCoCg-R.
  - Removes some spectral redundancy.
  - YCoCg can be losslessly converted to and from RGB.
  - No conversion is required for YCbCr color space but the values are mapped.
    - The Cb component is mapped to the Co component label.
    - The Cr component is mapped to the Cg component label.

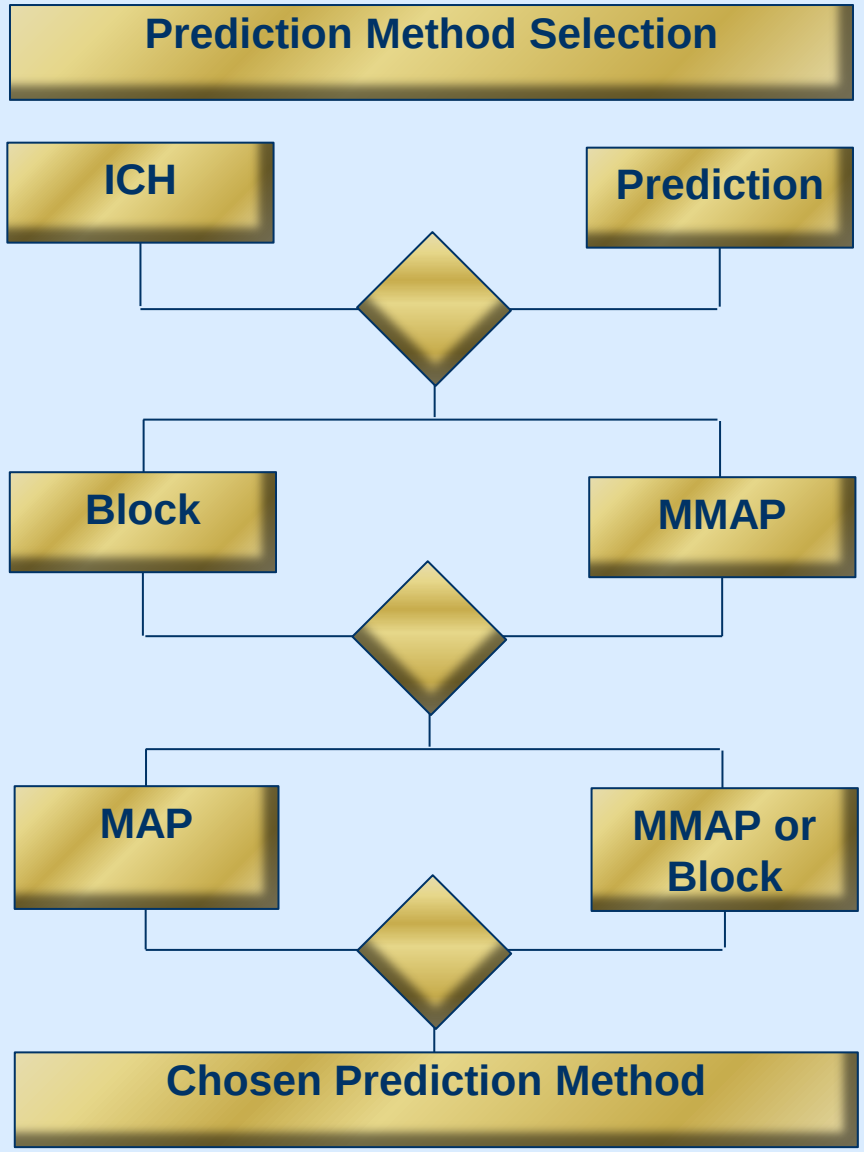
Display Stream Compression – Prediction Methods





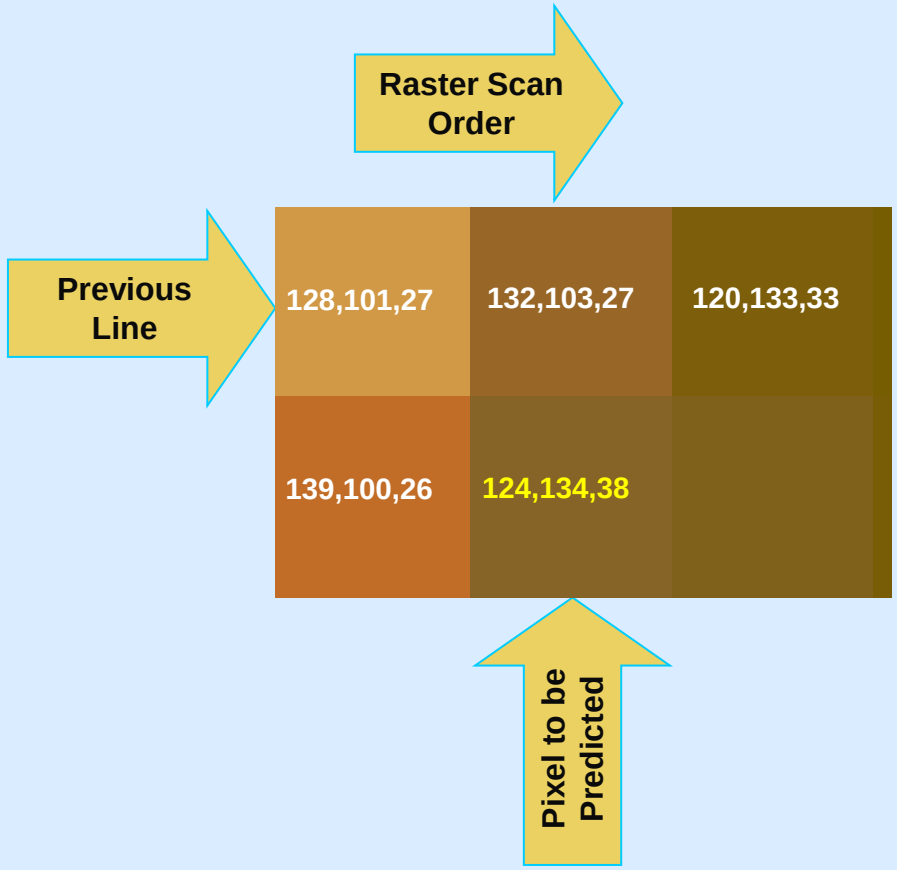
- Prediction Methods – Compare and Contrast
- DSC is a “prediction-based” visually lossless compression method.
  - Prediction uses an algorithm to **remove spatial redundancy** (intra-frame).
  - Prediction is based on the assumption that **pixel values can be inferred by knowing the neighboring (adjacent) pixel values in a frame**.
  - DSC uses the true pixel values, then subtracts the predicted pixel value to arrive at a “**Residual**.” It is the **quantized residual that is transmitted** across the link.
- There are three (3) prediction methods used in DSC:
  - Modified Median-Adaptive Prediction (MMAP):
    - The **default prediction met**hod.
    - Predicts the current pixel sample from the **coded samples to the left and above** the current sample.
  - Block Prediction (optionally supported by the sink):
    - Predicts the current pixel sample from the coded samples to the left of the current sample.
    - Uses a vector obtained from analysis of the previous scan line to point to a pixel group within the current pixel’s scan line.
  - Midpoint Prediction (MPP) – Uses midpoint of a pixel’s valid range to predict the sample. Used when the number of bits required to encode the largest quantized residual for a component is greater than the bit depth.
- The **encoder and decoder automatically select prediction method using the same algorithm**.

Display Stream Compression – Choosing Prediction Methods



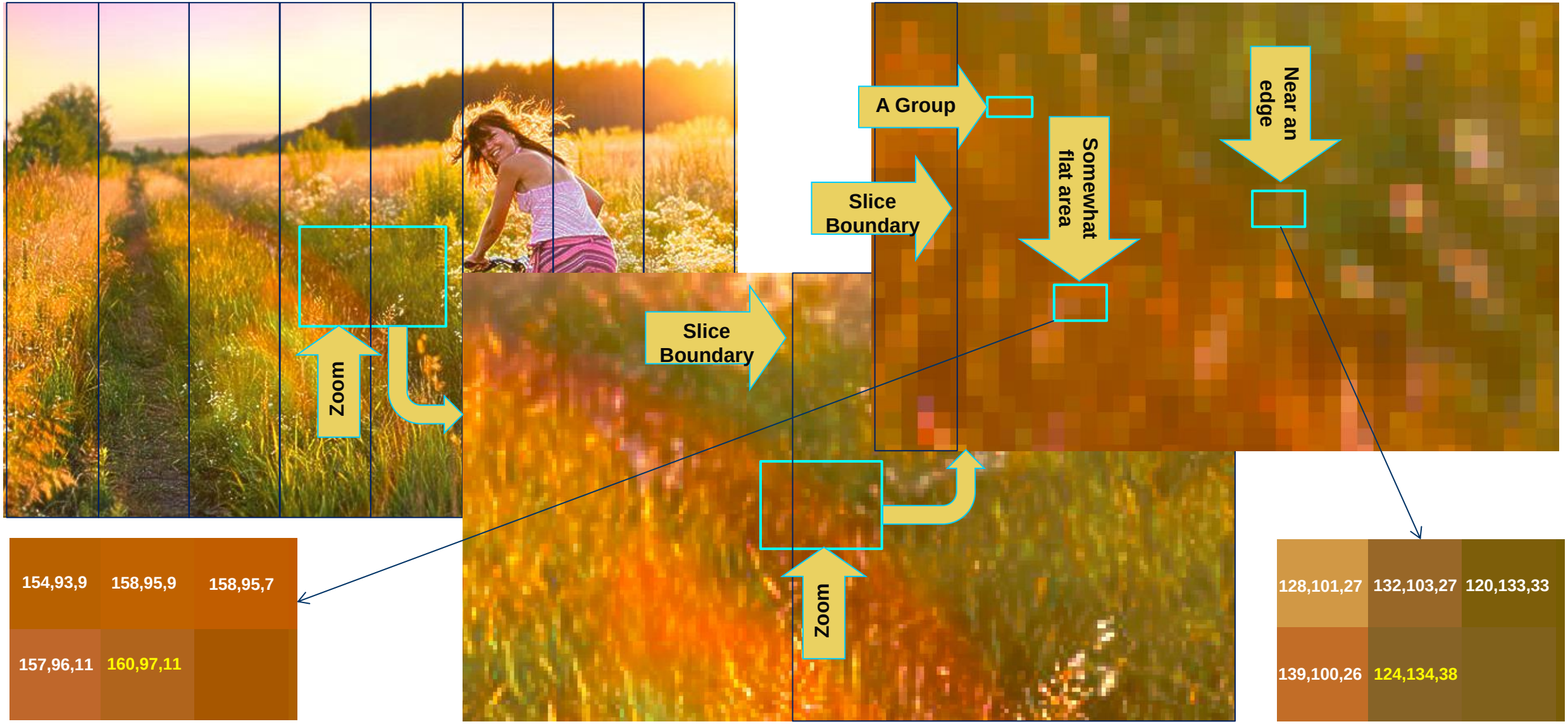
- Choosing the Prediction methods – Quick Facts
  - Encoder first selects between Prediction and Index Color History (ICH).
  - Encoder then selects between Modified Median-Adaptive and Block Prediction (if Block Prediction is supported in the decoder).
    - **Selection is made on a DSC Group basis**.
    - Selection is **not signaled over the bit stream** from DSC encoder to DSC decoder.
    - The **algorithm followed is the same between the encoder and decoder** and therefore the selection is made based on the image content, specifically previous pixel values that are in close proximity to the pixel group being encoded/decoded.
  - Selection between MMAP/Block and Midpoint Prediction.
    - Selection is made based on the size of the quantized residuals that would be generated if MMAP or BP were selected.
    - Selection is **not signaled over the bit stream** from DSC encoder to DSC decoder.

Display Stream Compression – MMAP Prediction Method

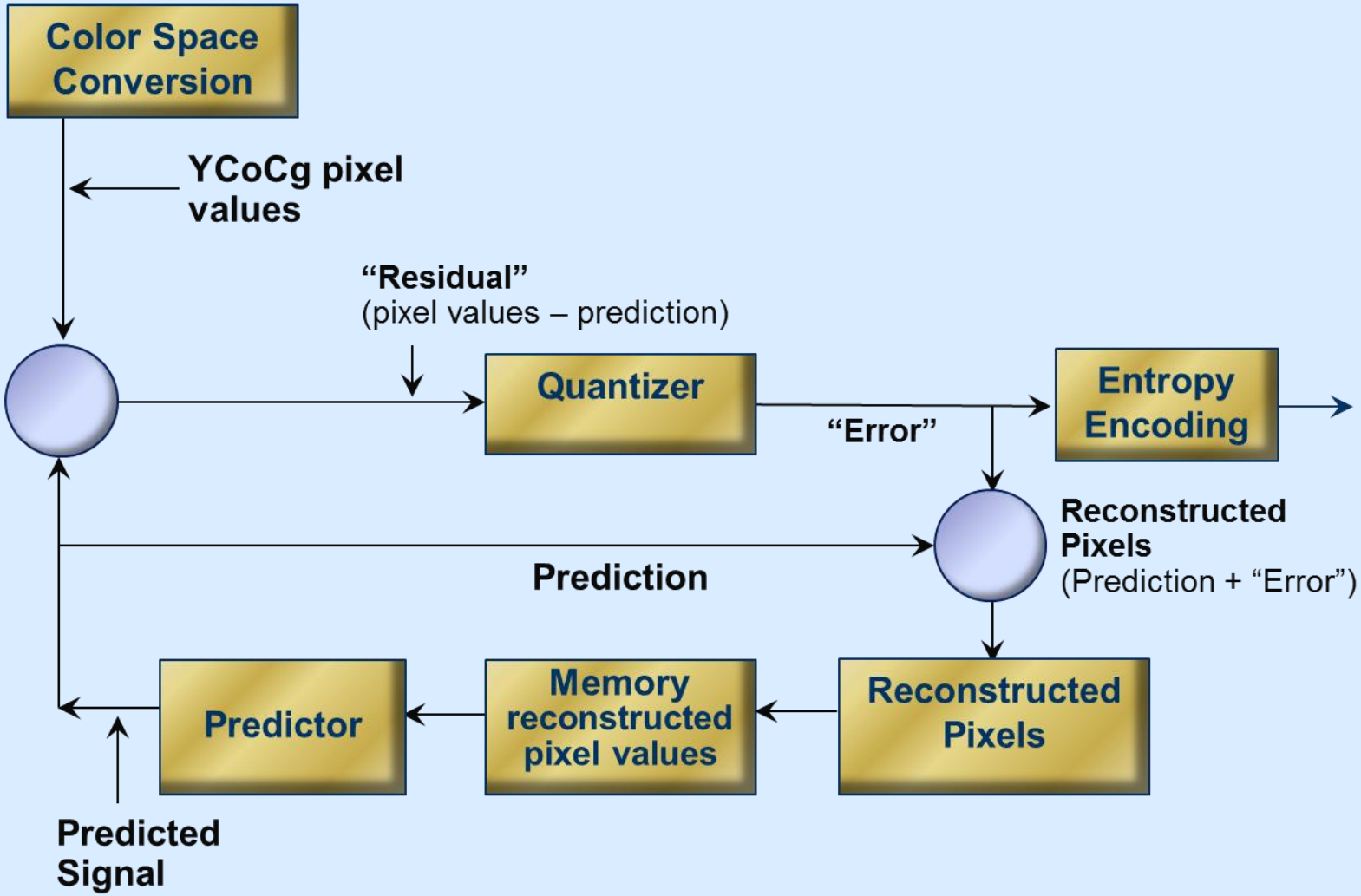


- Modified Median-Adaptive (MMAP) method – Quick Facts:
  - Median adaptive prediction (MAP) is a well-known prediction method that is used in the Joint Photographic Experts Group-Lossless Standard (**ITU-T Rec. T.87** | ISO/IEC 14495-1).
  - Prediction is done on one component (sample) in each group at a time (e.g. Y or Co or Cg).
  - Prediction uses adjacent but prior pixels (previous line or previous pixel in the same line.)
  - If one of the adjacent pixels is outside the slice, **pixel replication** is used to fill those inputs.
  - In the case of the first line of a slice, the previous line's pixels are not available so **extra bits are allocated** to the first line to reduce video artifacts on the top boarder of a slice.
  - In Native 4:2:0 mode, the previous line's chroma samples are not available for both the first and second line of a slice.

Display Stream Compression – MMAP Prediction Method

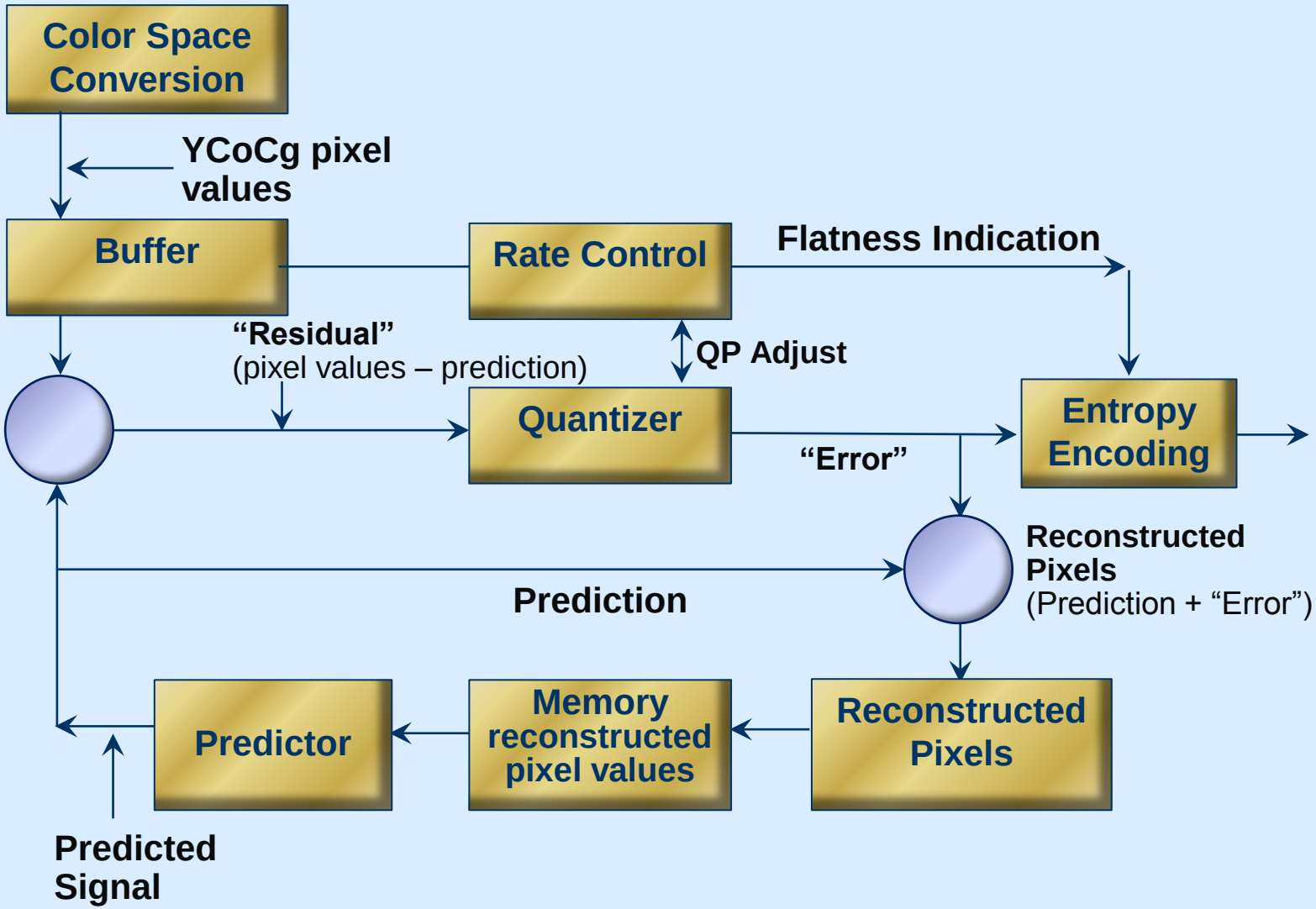


Display Stream Compression – Encoder Prediction Operation



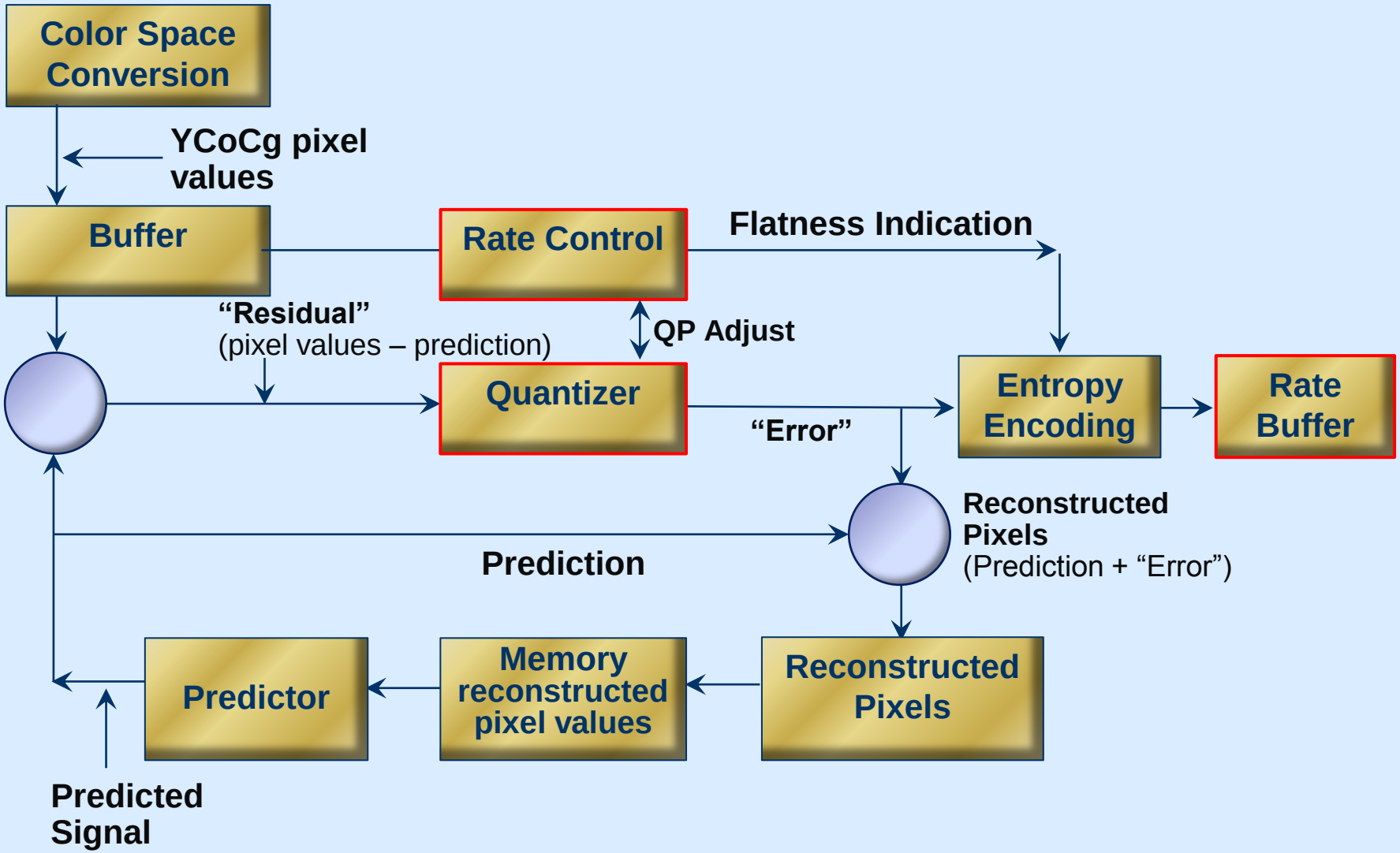
- DSC compression is based on Differential Pulse Code Modulation (DPCM) methods to predict the current pixel from adjacent pixels and encodes the difference between the original pixel values and predicted pixel values to produce a "Residual."
- A quantizer converts the Residual into a quantized (an "Error"). It is the prediction residual with the quantized error (not the original pixel values) that is transmitted to the decoder over the display link.
- However, the predictor must use "reconstructed pixels" in the prediction, not the actual pixel values. Why?:
  - Use of the reconstructed (decoded) pixels ensures that the prediction signal is identical in the encoder and decoder.
  - Because the original pixels are not available in the decoder side, the use of.
  - If the encoder used the original pixels for prediction, there would be an accumulation of error "Error Drift."

Display Stream Compression – Encoder Flatness Indication & QP Adjustment



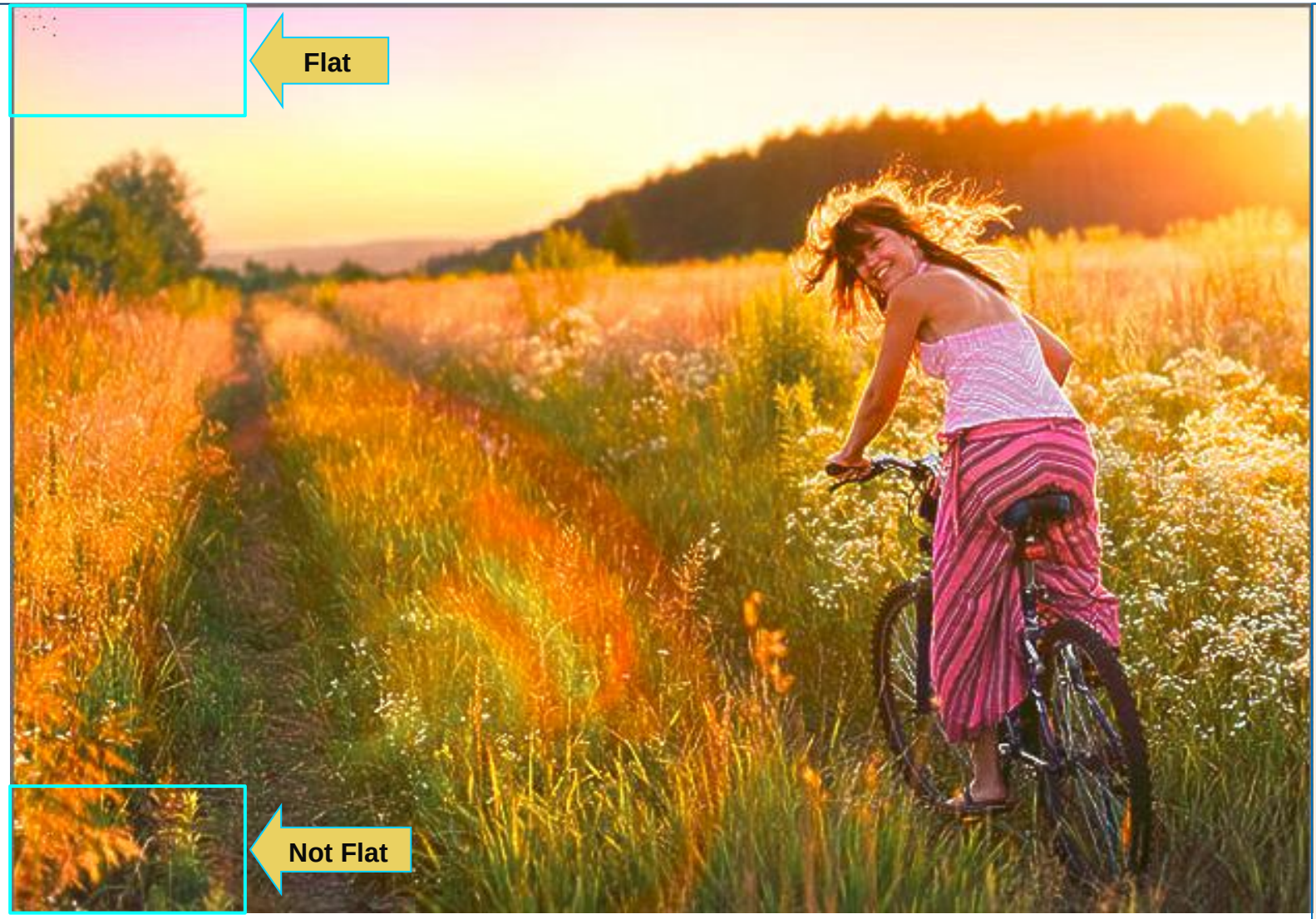
- "Flatness" is **a measure of smoothness** or similarity in pixel values throughout a region in the picture.
- Flatness is used by the Rate Controller to adjust the "**Quantization Parameter**" (QP) which allows the quantization to introduce more or less error depending on the flatness.
- There two (2) levels of flatness: 1) Very Flat and 2) Somewhat Flat.
- The **flatter the region the less errors that can be tolerated** they are far more noticeable then "busy" areas.
- Flatness determination uses a "**Super Group"** which is four consecutive groups.
- The **indication of flatness** can occur every four groups and **is transmitted** using a code sequence **in the first luma substream** in the Super Group.
- The original uncompressed pixels are used in the flatness determination.

Display Stream Compression – Rate Control



- Rate Control – Quick Facts.
  - The Rate Controller does two (2) things:
    - **Sets the Quantization Parameter** (QP) for each Group.
    - Converts a varying number of bits for each group into a specified constant bit rate to ensure that the Rate Buffer does not overflow or underflow.

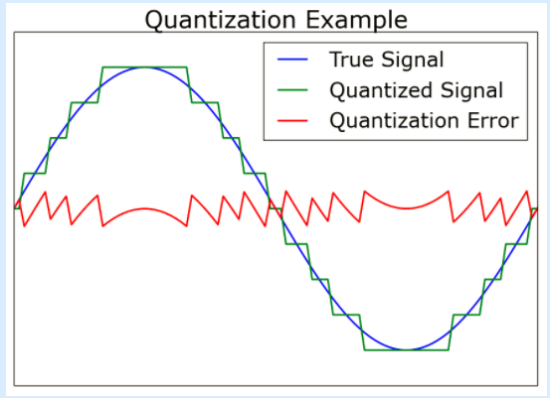
Display Stream Compression – Encoder Flatness Indication & QP Adjustment

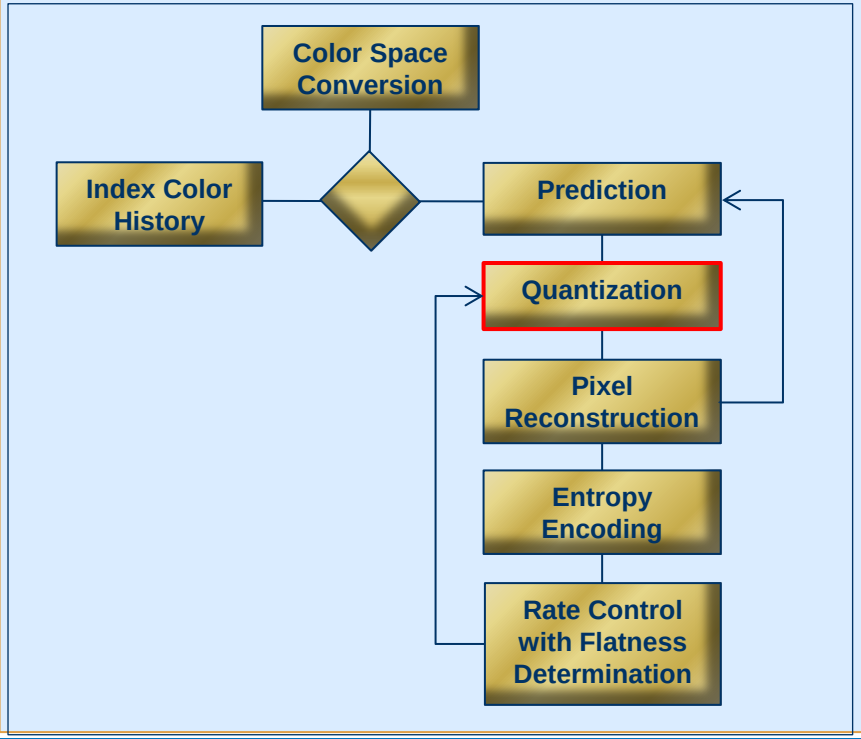


- Flatness / QP – Quick Facts.
  - Flatness is detected and used by the Rate Controller to adjust the “Quantization Parameter” (QP) which allows the quantization to introduce more or less error depending on the flatness.
  - The more flat an area of the image, the lower the QP.
  - Image to right has pixel errors introduced in both the “Flat” region and the “Not Flat” region.

  Note: The pixel errors are only noticeable in the Flat region.

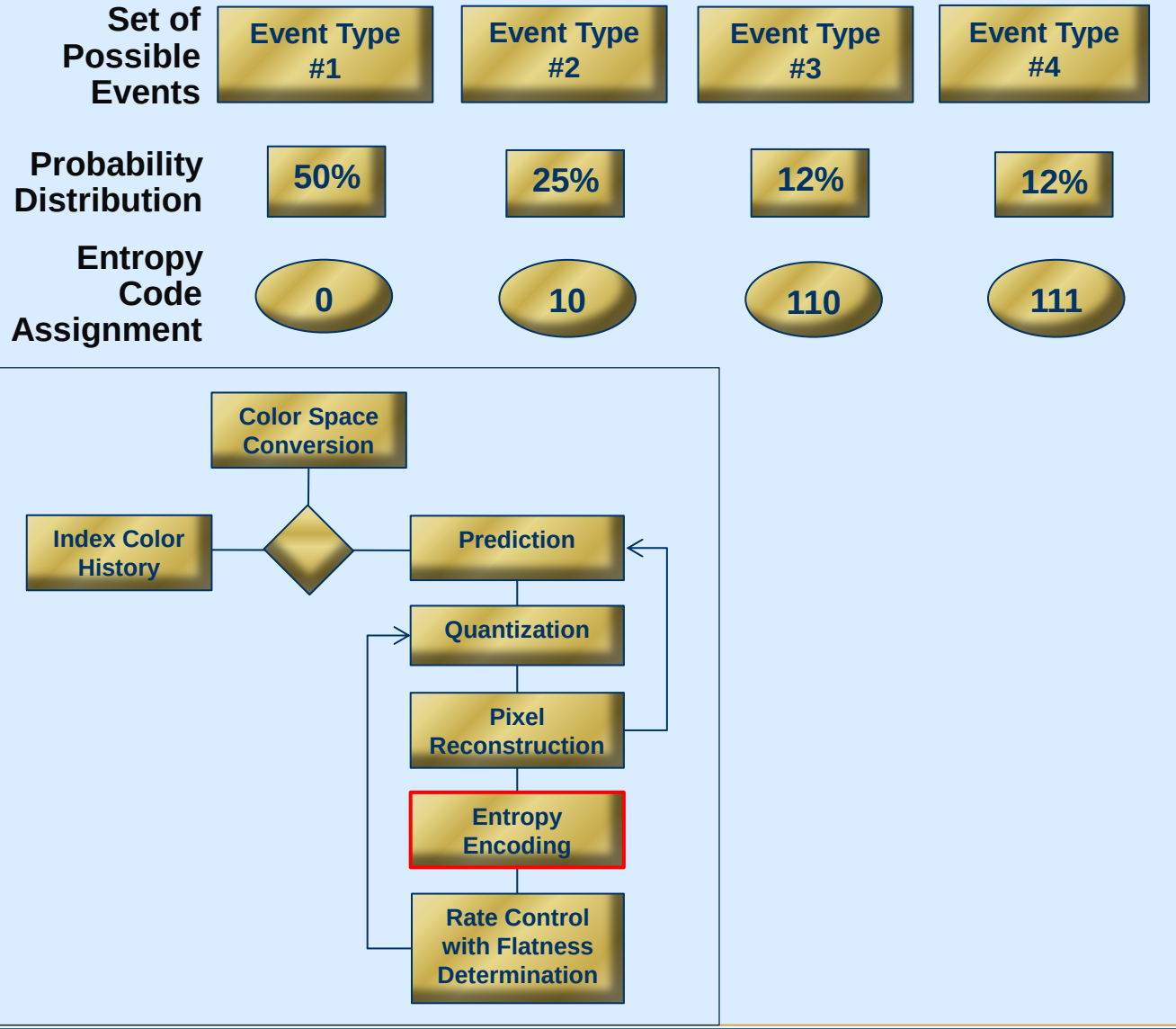
Display Stream Compression – Quantization





- Quantization – Quick Facts
- The predicted value is subtracted from the original pixel value to produce a "**Residual**."
- The residual is quantized, i.e. assigned a value; the result is referred to as an "Residual Error."
  - Quantization maps a range of inputs to a more limited set of assigned integers.
  - Quantization is involved in all digital signal processing.
  - Digital signal processing can only work with integers.
  - There is always a loss of information (introduction of errors) in quantization.
  - Typically, quantization is used to map a continuously varying time signal to an integer.
  - In a DSC encoder, quantization involves taking a prediction residual value (difference between the actual pixel and the prediction for that pixel) and **using division with truncation and rounding to produce a quantized value**, a "Residual Error".
  - Quantization Parameter is **set by the Rate Control** mechanism based on "Flatness" of a "**Super Group**" (4 Groups).

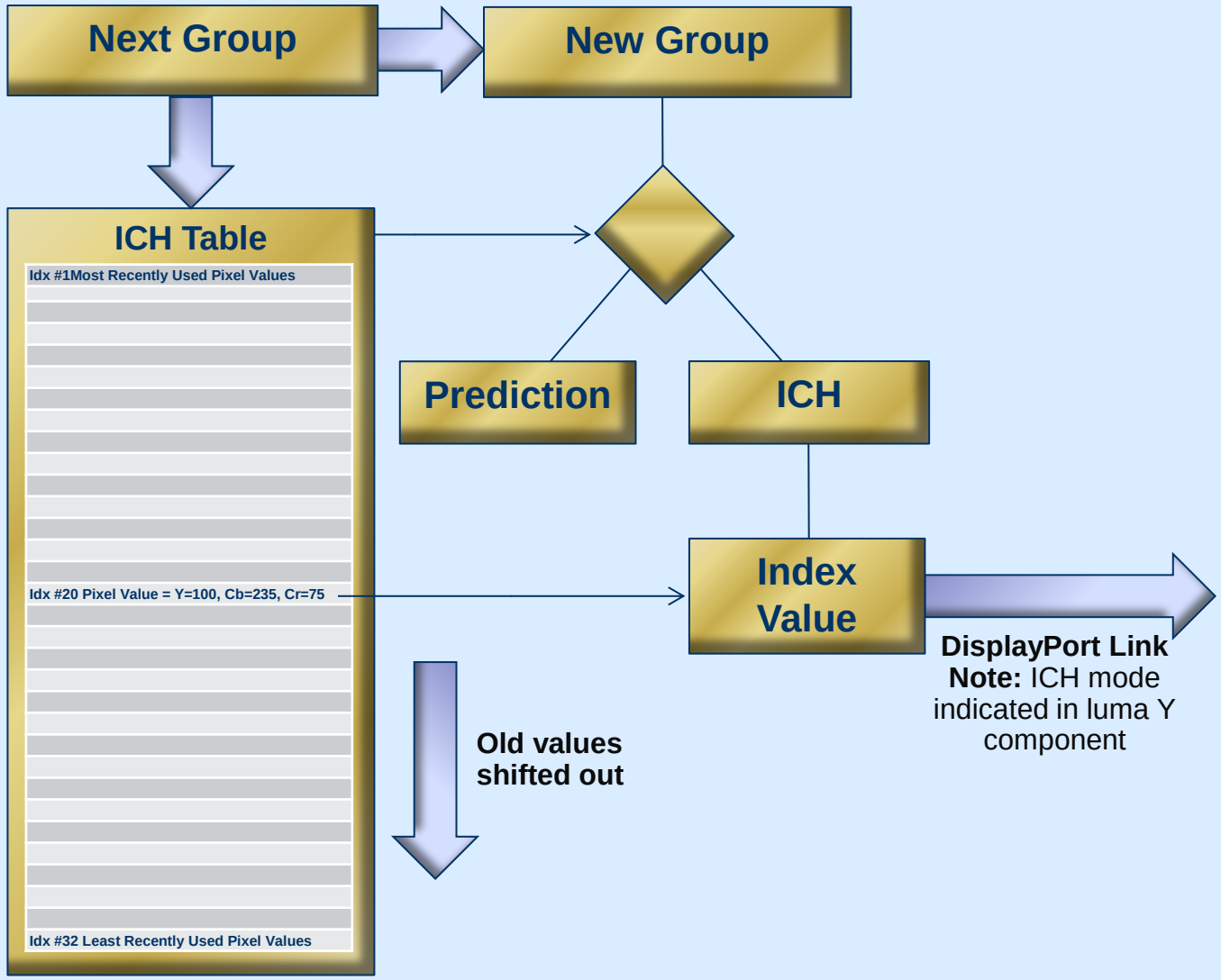
Display Stream Compression – Entropy Encoding



- Entropy Encoding – Quick Facts.
  - **Entropy** in Information Theory is the measure of randomness or degree of disorder. **The extent to which all possible outcomes are equally likely**.
  - When entropy is high (e.g. dice throws), it is infeasible to predict an output better than pure random chance.
- Entropy Encoding.
  - Entropy encoding is **a way of encoding values such that the more frequently occurring values are encoded with fewer bits than the less frequently occurring values (Left)**.
  - Morse code uses entropy encoding:

    "E" = · vs "Z" = — · — —
  - Encodes the "Residual Error" to further compress the signal by **removing statistical redundancy**. It reduces the number of bits used to encode a signal.
  - **When the Prediction mode is used**, the prediction "Residual Error" is entropy encoded and is packaged in Delta Sized Unit – Variable Length Coding (DSU-VLC).
  - DSU-VLC organizes the samples into "Units (the coded set of predicted residuals of three (3) consecutive samples (Y, Co, Cg)).

Display Stream Compression – Indexed Color History (ICH) Operation



- DSC Indexed Color History - Quick Facts:
  - ICH mode is an alternative DSC compression mechanism to Prediction.
  - The DSC encoder determines whether to use the ICH mode on a **pixel group by pixel group basis.**
  - ICH is useful on **computer graphics where certain pixel values occur very commonly**.
  - ICH uses a “Storage Unit”, i.e. a dynamic table with the recent history of reconstructed pixel values.
  - There are 32 values in the Index Color History storage unit.
  - The ICH process assigns a 5 bit “Index Value” that points to a location in the table.
  - It is these Index Values that are transmitted over the display link to the decoder.
  - The **encoder and decoder have the same ICH table of values**.
  - The **encoder signals over the bitstream** to the decoder that it will use ICH by a special bit sequence **in the luma (Y) substream**.

DisplayPort DSC Protocol Operation

Webinar – February – 2018

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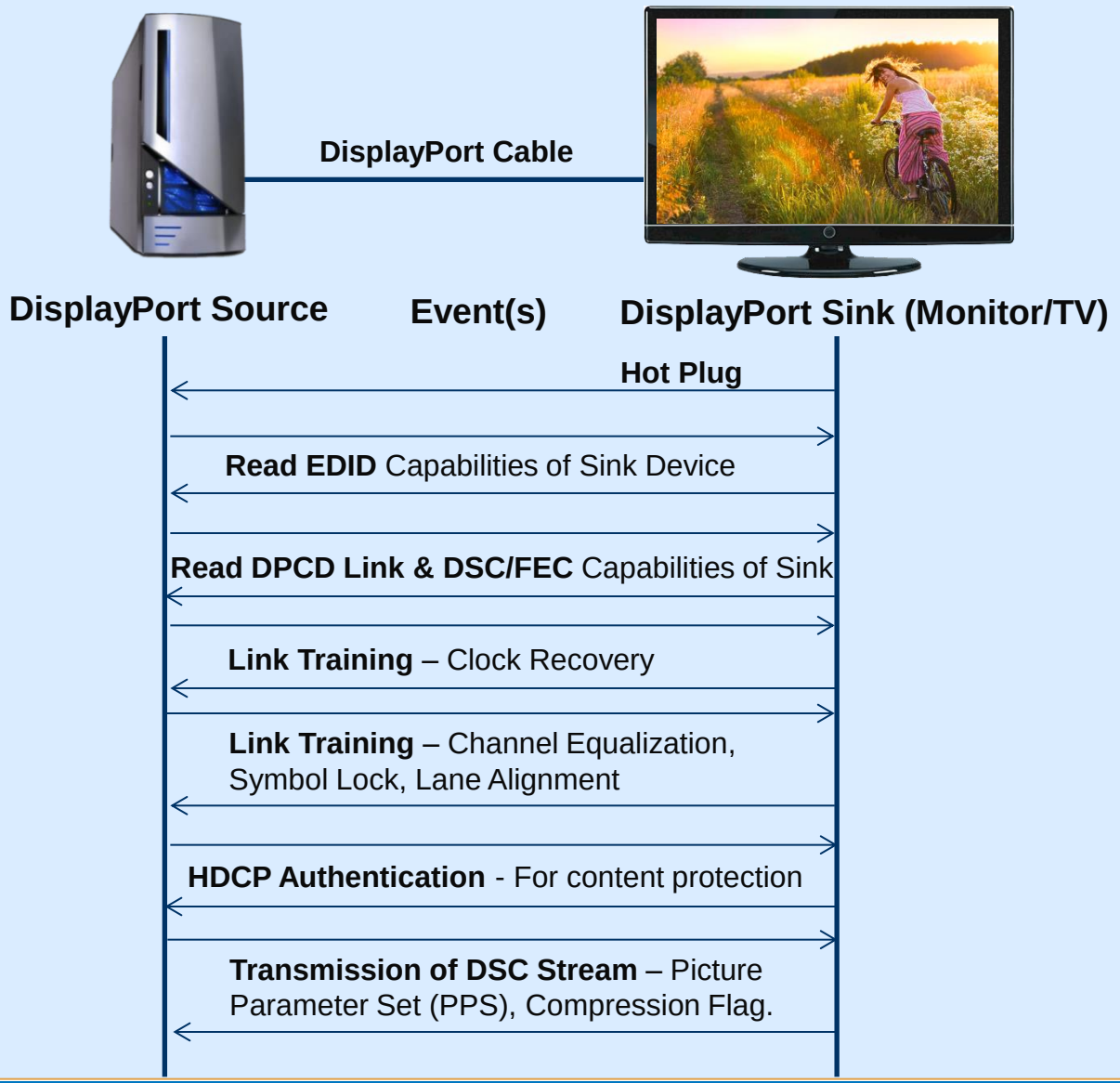
DisplayPort DSC Protocols

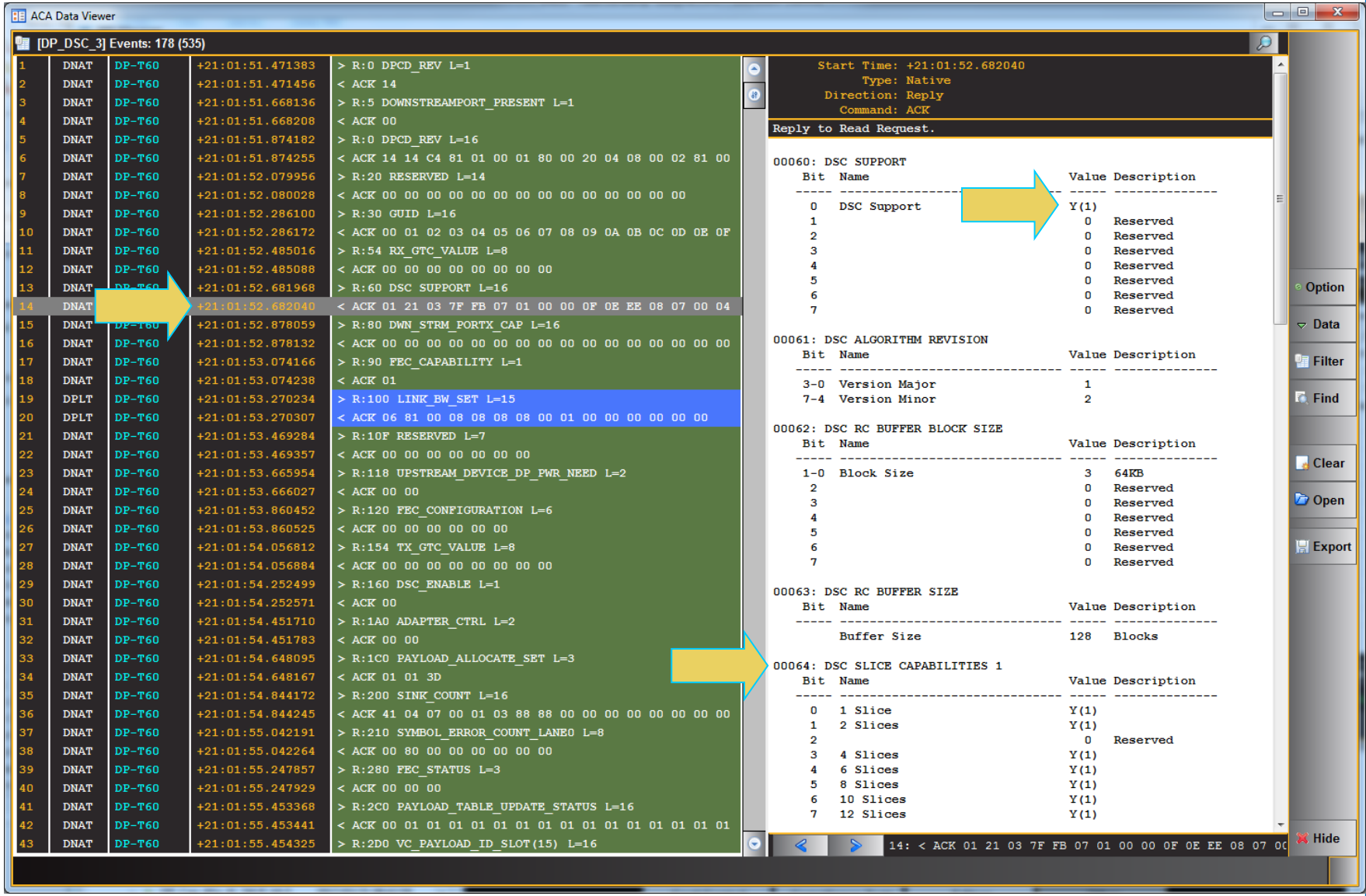
Configuration, Discovery, Enabling/Disabling

Display Stream Compression – Configuration, Discovery, Enabling



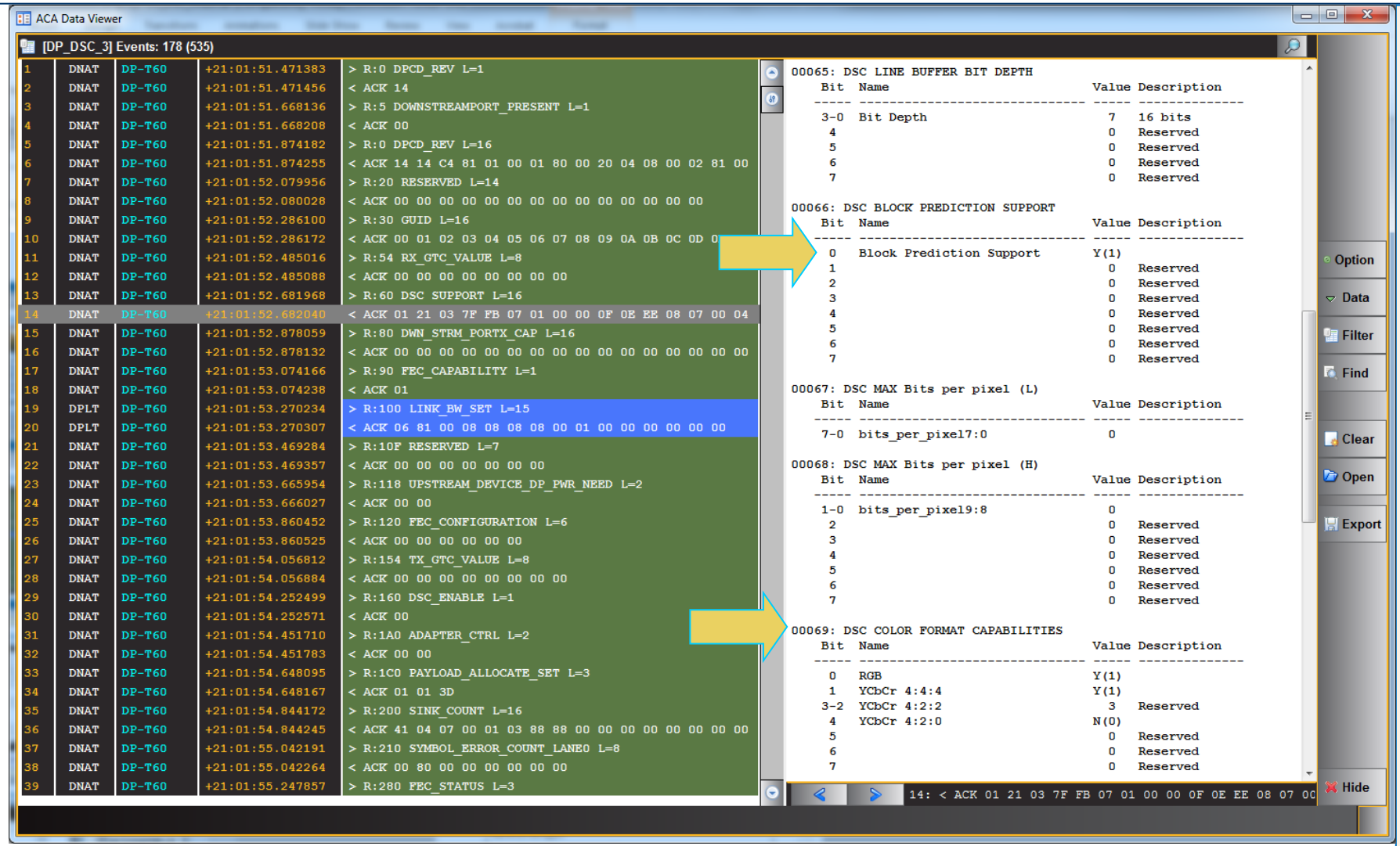
- Hot Plug. Indication to the Source that there is a Display device connect to it.
- EDID read. EDID is a data structure provided by a DisplayPort display that describe its capabilities to a DisplayPort video source.
- DPCD read. DPCD is a data structure provided by a DisplayPort device that describe its link & DSC capabilities to a DisplayPort source.
- Link Training. Link training establishes the physical link parameters (number of lanes, link rate, voltage swing, pre-emphasis, equalization) used for transmission of video and audio over the main link.
- Link Training has two phases:
  - Clock Recovery and
  - Channel Equalization which includes Symbol Lock and Inter-Lane alignment.
- If the video/audio content is flagged for content protection, the High-bandwidth Digital Content Protection (HDCP) authentication protocol is used.
- **Compressed, encrypted video transmission is initiated. Picture Parameter (PPS) metadata is transmitted, VB-ID compressed flag is set.**

DSC Configuration, Discovery, Enabling – Reading Sink DPCD Registers



- Source reads sink DPCD registers to determine DSC capabilities of sink.
- Example showing the following registers:
  - DSC Support. **Indicates if DSC is supported** in the DP sink.
  - **DSC Algorithm** Revision. Version of DSC supported.
  - DSC Rate Control Buffer Block Size. Block size of the memory blocks in the Rate Control Buffer.
  - DSC Rate Control Buffer Size – Number of RC memory blocks.
  - DSC Slice Capabilities – **Indicates the number of slices** supported.

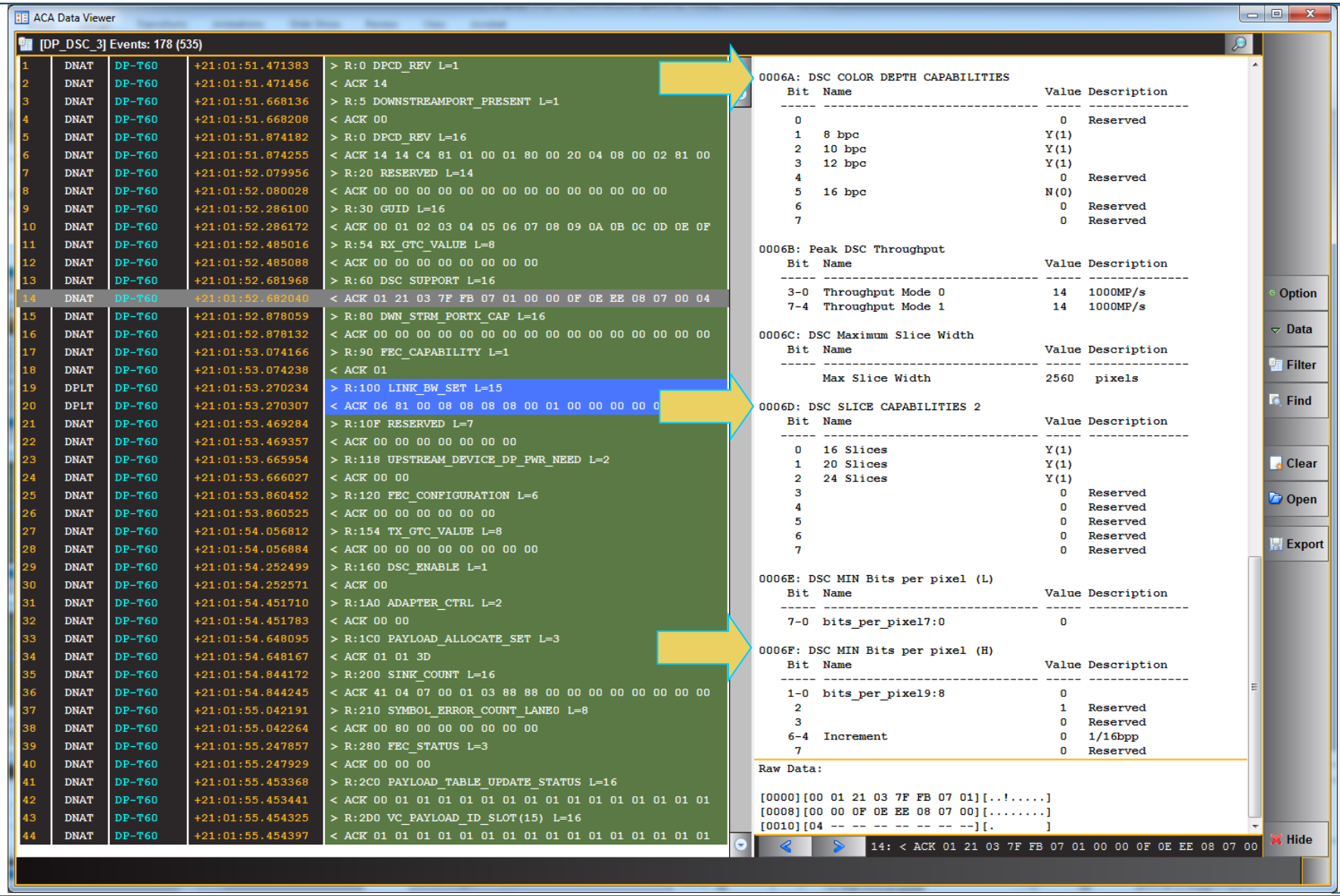
DSC Configuration, Discovery, Enabling – Reading Sink DPCD Registers



- Example showing the following registers:
  - DSC Line Buffer Bit Depth – The bit depth used in the sink's decoder to store the reconstructed pixels.
  - DSC Block Prediction Support – **Indicates whether the Block Prediction method is supported**.
  - DSC Maximum Bits per Pixel – The **maximum pixel depth** of the incoming video signal that can be compressed.
  - DSC Color Format Capabilities – The **colorimetry types supported** in DSC mode. This includes which chroma subsampling methods are supported.

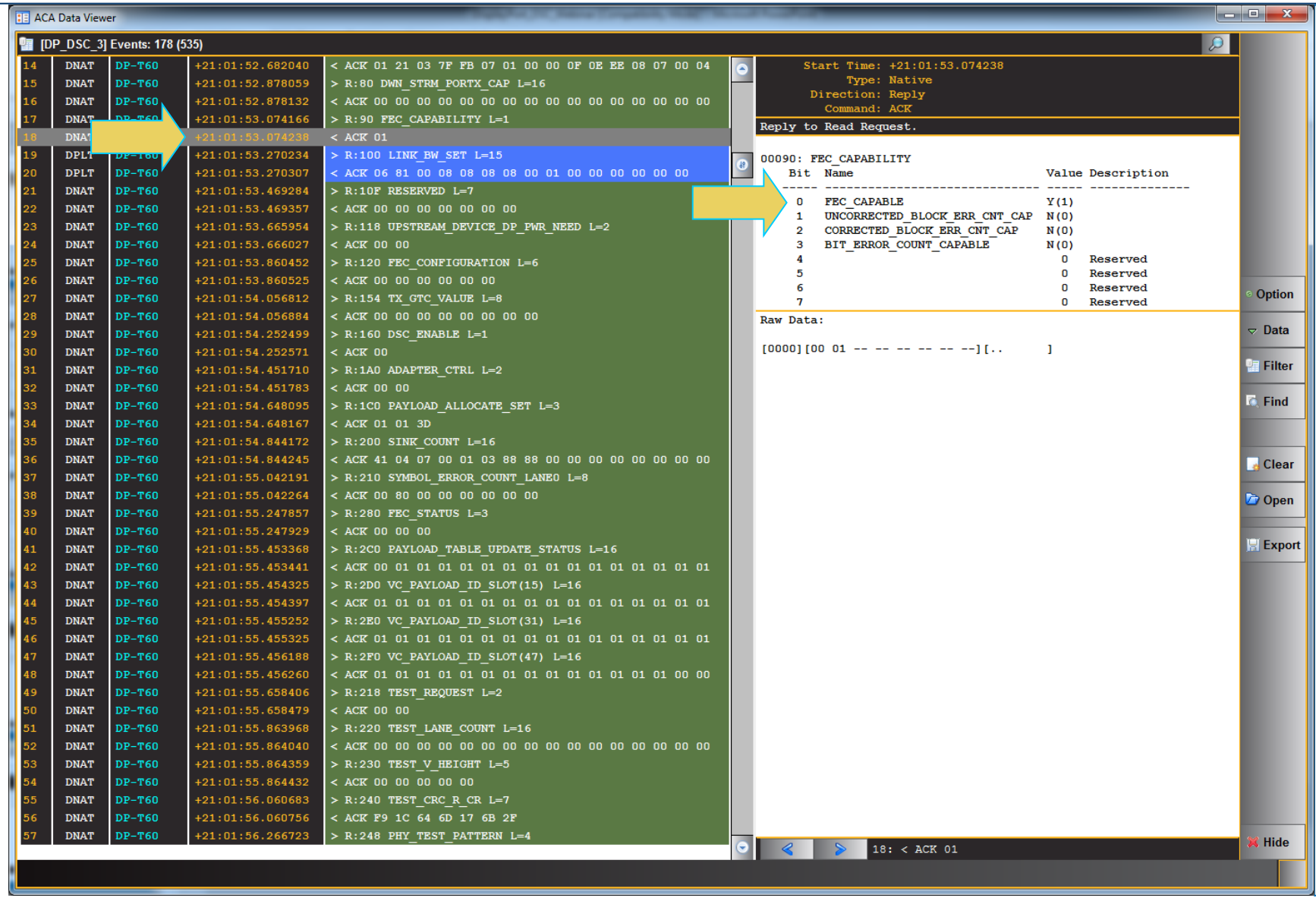
DPCD	Register	Read/Write

DSC Configuration, Discovery, Enabling – Reading Sink DPCD Registers



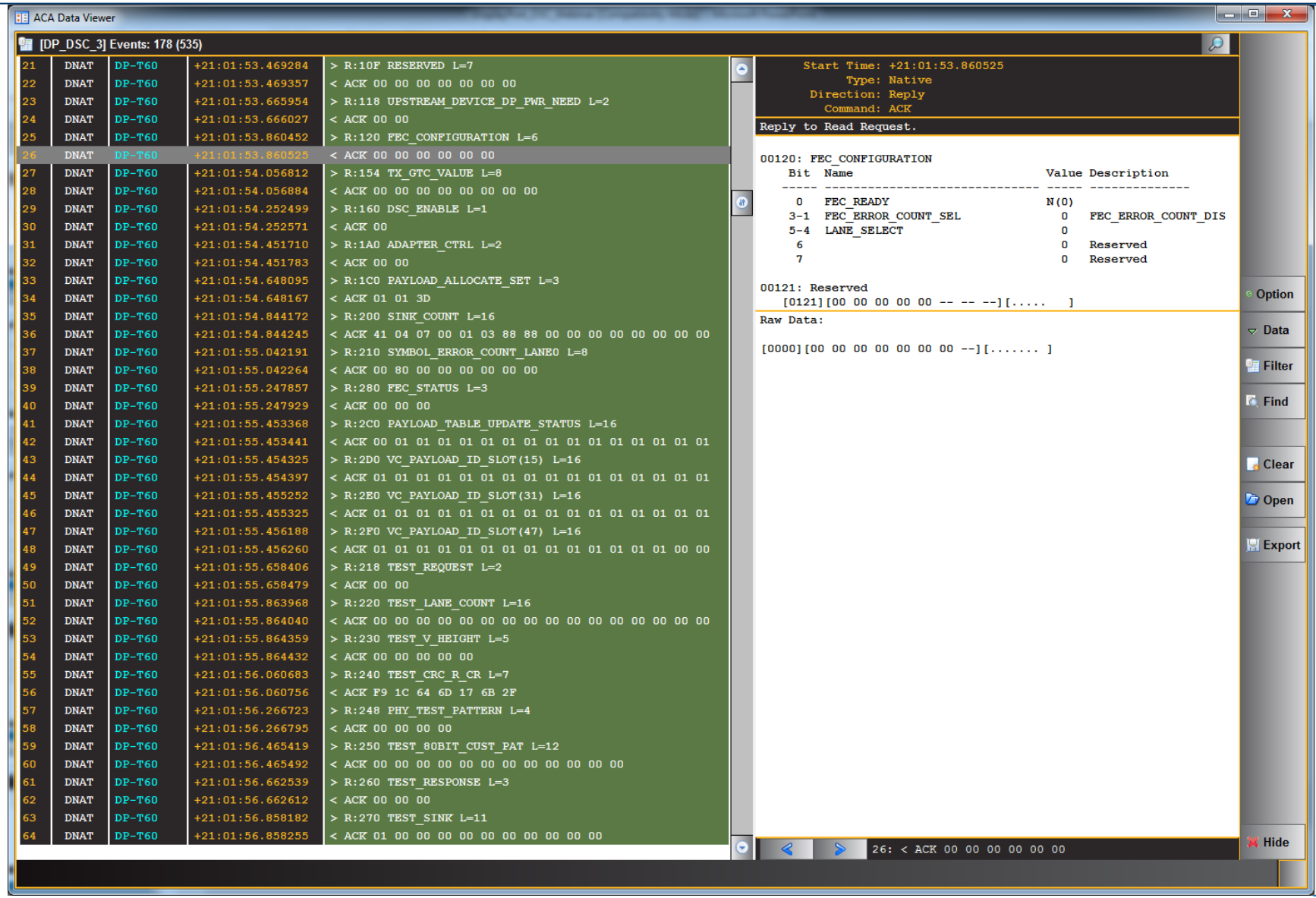
- Example showing the following registers:
  - DSC Color Depth Capabilities – The **color bit depths supported** in DSC mode.
  - Peak DSC Throughput – Peak data rate expressed in MP/s from 340MP/s to 1000MP/s.
  - DSC Maximum Slice Width – **Maximum slice width supported** by the DSC sink decoder.
  - DSC Slice Capabilities – **Number of slices supported** by the DSC sink decoder (continued).
  - DSC Minimum Bits per Pixel – Minimum bit depth supported by the sink DSC decoder.

DSC Configuration, Discovery, Enabling – Reading Sink DPCD Registers



- Source reads sink DPCD registers related to Forward Error Correction (FEC) capabilities which is required for DSC transmission.

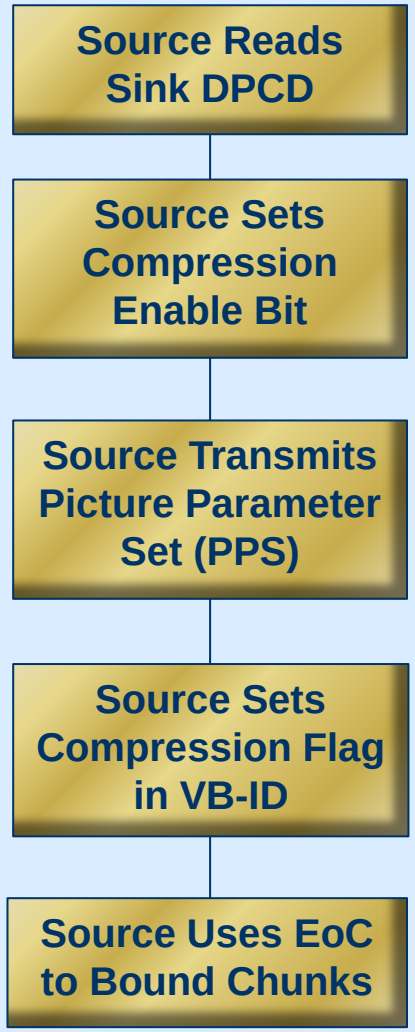
DSC Configuration, Discovery, Enabling – Reading Sink DPCD Registers



- Source reads sink DPCD registers related to Forward Error Correction (FEC) Configuration.

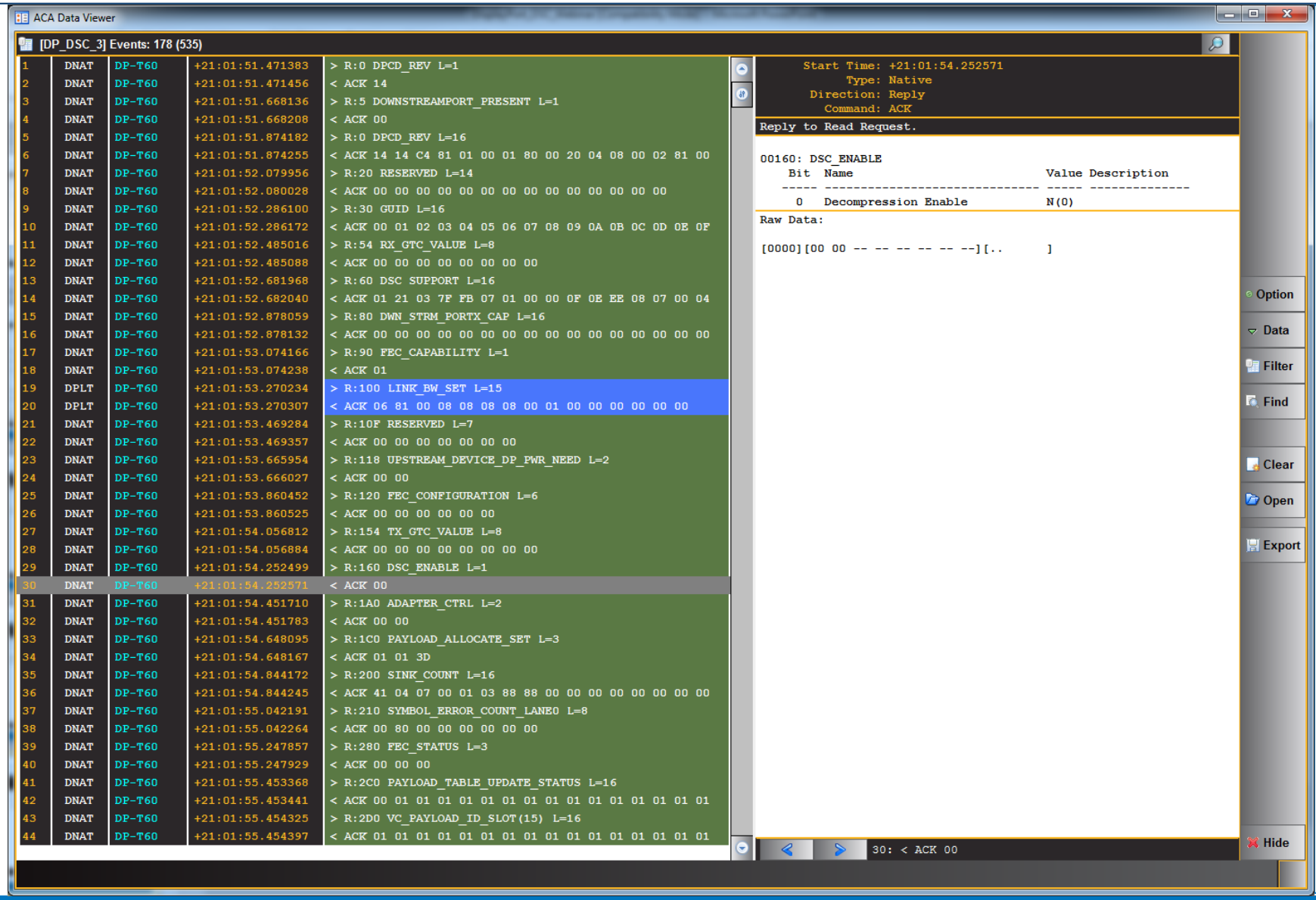
DisplayPort DSC Protocols
Main Stream Protocols
VB-ID Compression Flag

Display Stream Compression – Compression Enabling



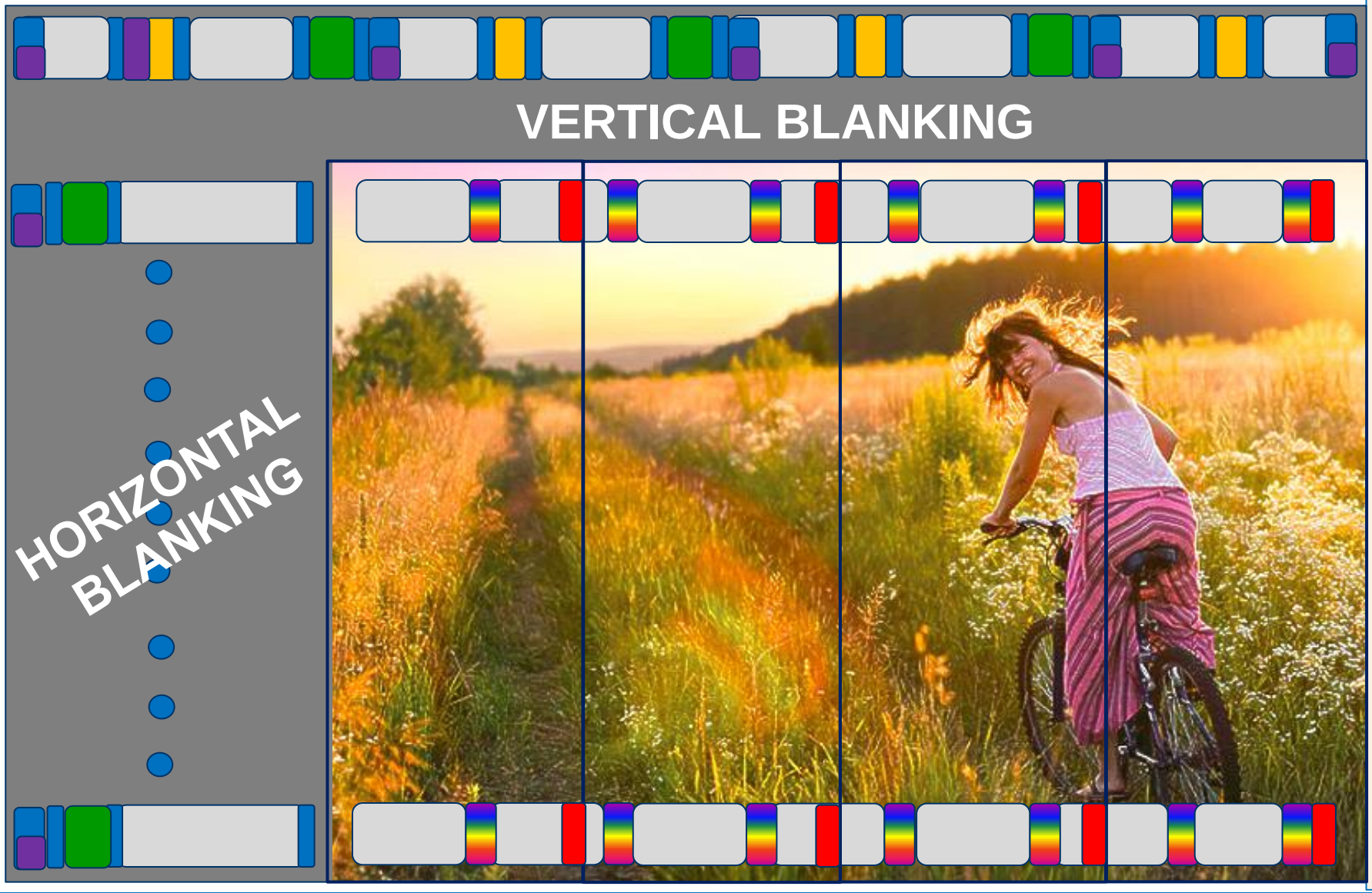
- Sequence of events to enable compression.
  1. Source reads sink DPCD registers related to DSC.
  2. Source sets the sink Compression Enable bit in the DPCD register.
  3. Source transmits the Picture Parameter Set (PPS) over the main link.
  4. Source sets the VB-ID (Video Blanking Identifier) Compression Flag.
  5. Source terminates all compressed video lines within a Slice with the End of Chunk (EoC) packet.

DSC Configuration, Discovery, Enabling – Setting Compression Enable Bit



- Source writes Compression Enable bit to sink DPCD register then reads the status of the Decompression Enable bit.

DisplayPort Main Link Protocol – One Video Frame



- A compression flag is set in the VB-ID packet at the periodically through vertical and horizontal blanking.
- A single Picture Parameter Set (PPS) occurs near the beginning of a frame in the vertical blanking.
- An End Of Chuck (EoC) K-character occurs at the end of each chunk in each compressed line of video.

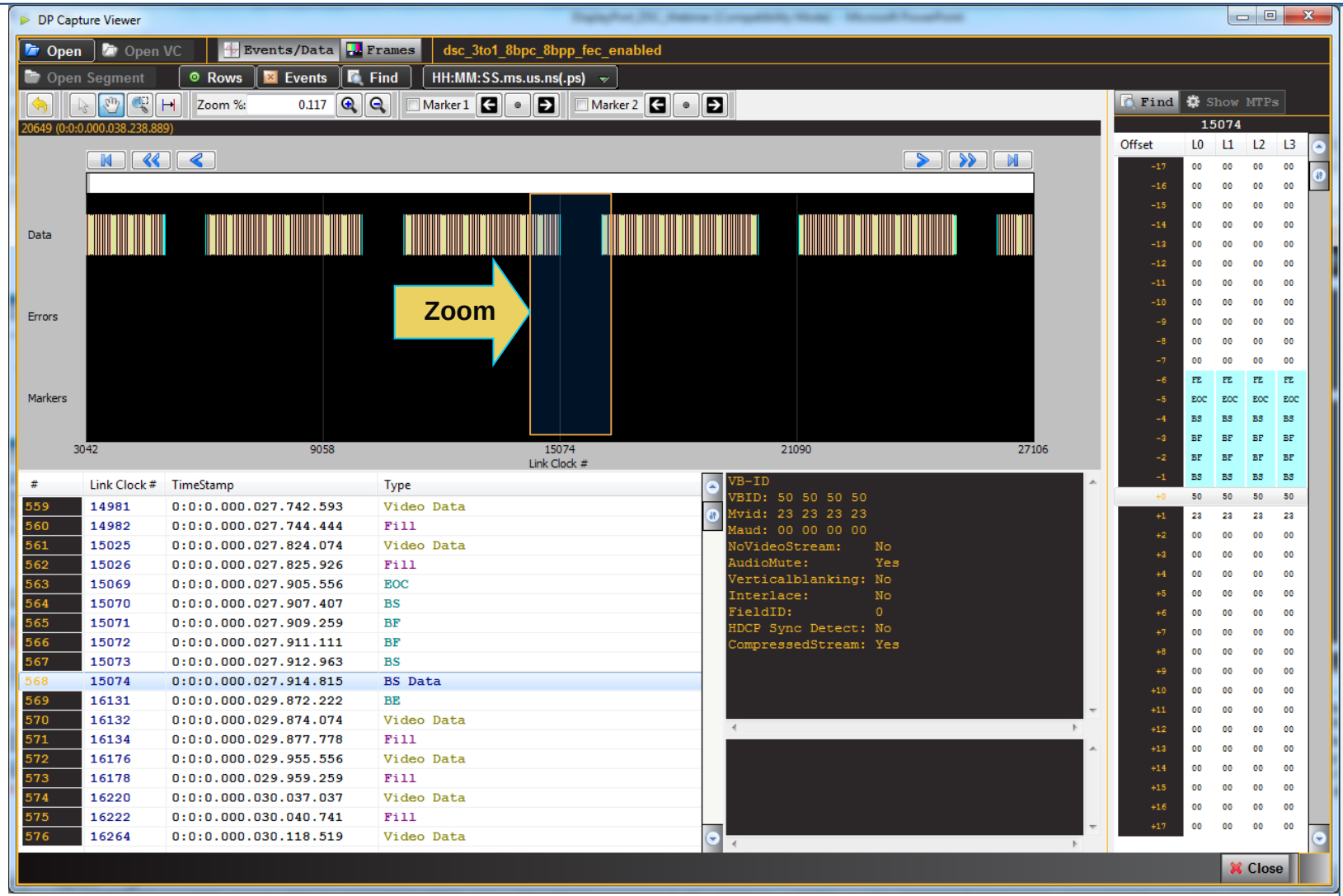
Video **Fill Characters**

Metadata **Control Symbols**

Audio **Control VBID w/ Compression Flag Set**

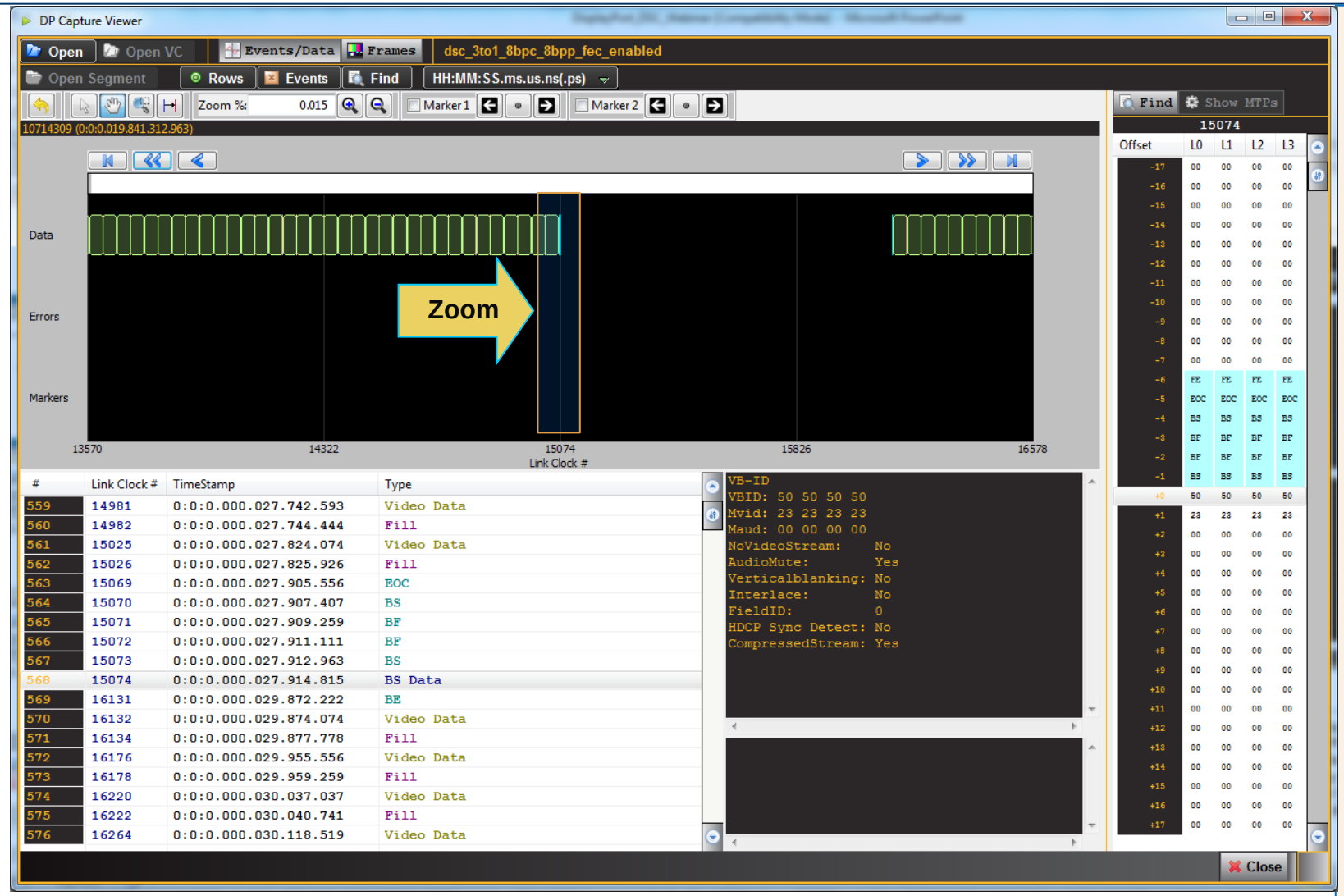
PPS **EoC**

Display Stream Compression – VB-ID Compression Flag



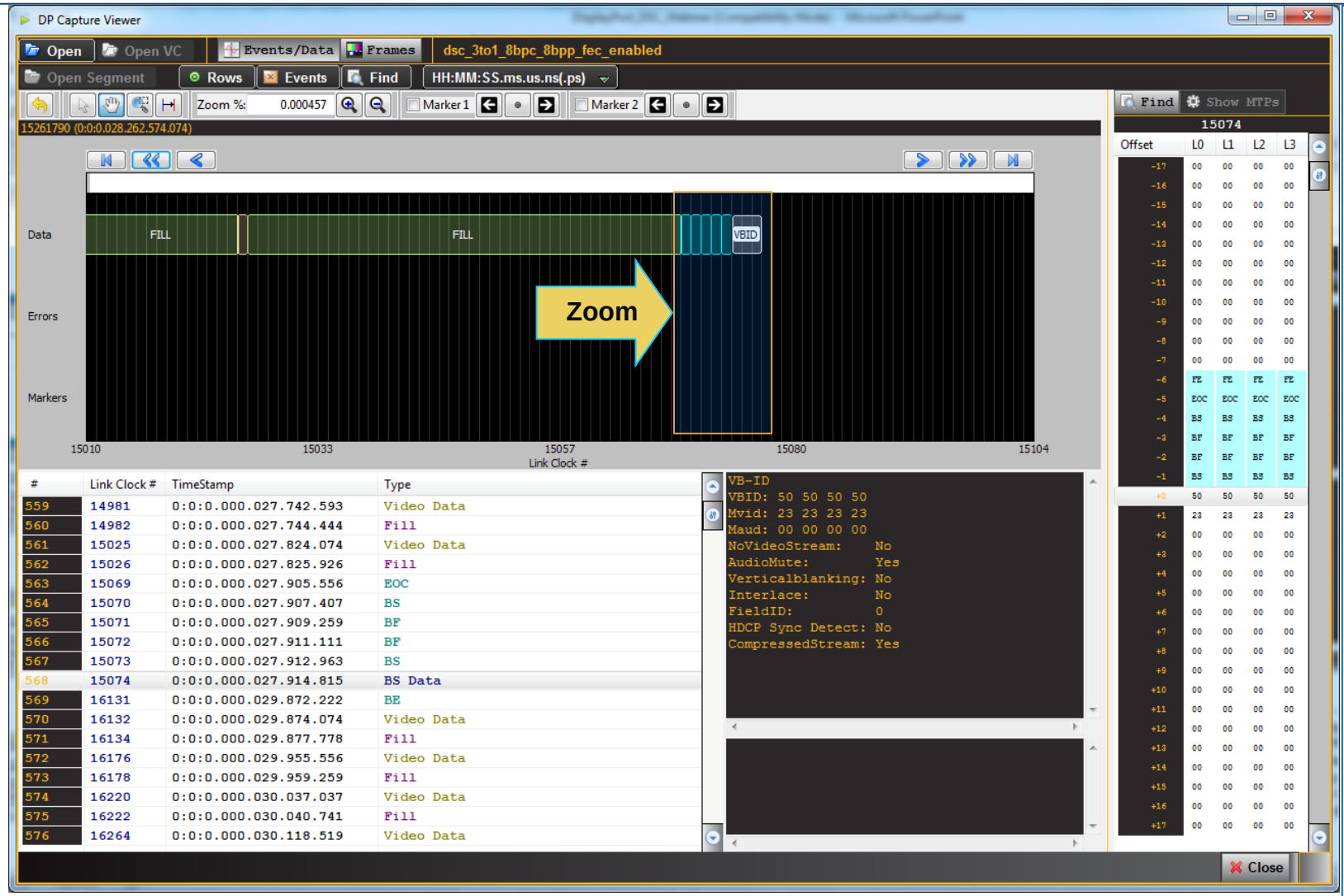
- VB-ID showing compression flag.
  - VB-ID Compression Flag must be set by the source when transmitting compressed video.
  - The Compression Flag is set one scan line prior to the active video region.
  - Compression Flag setting is not changed during the active region.

Display Stream Compression – VB-ID Compression Flag



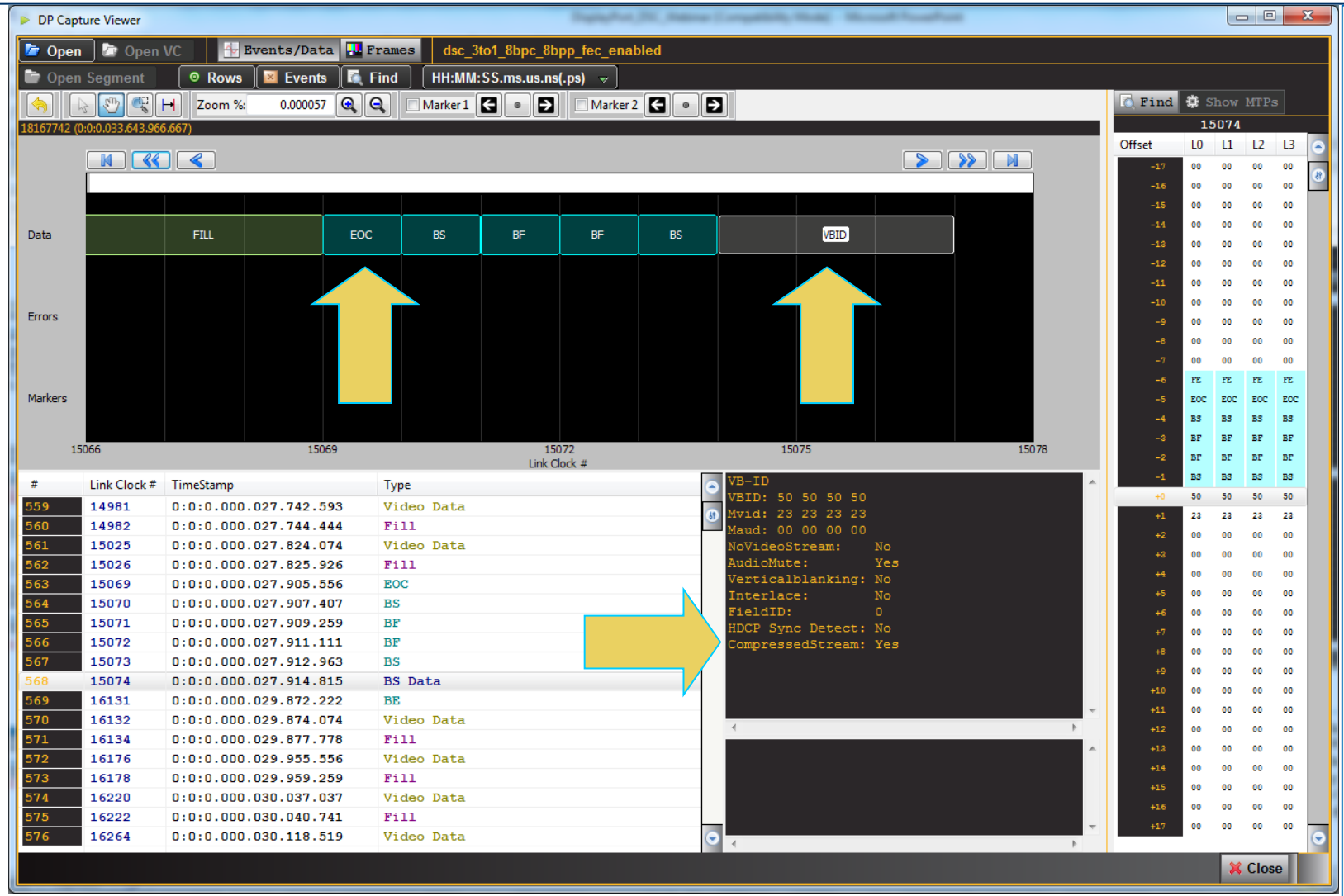
- VB-ID showing compression flag.
  - Zoomed in view showing end of a line of video with the VB-ID packet with the Compression Flag set.

Display Stream Compression – VB-ID Compression Flag



- VB-ID showing compression flag.
  - Zoomed in further showing last video packet in a video line with the VB-ID packet with the Compression Flag set.

Display Stream Compression – VB-ID Compression Flag



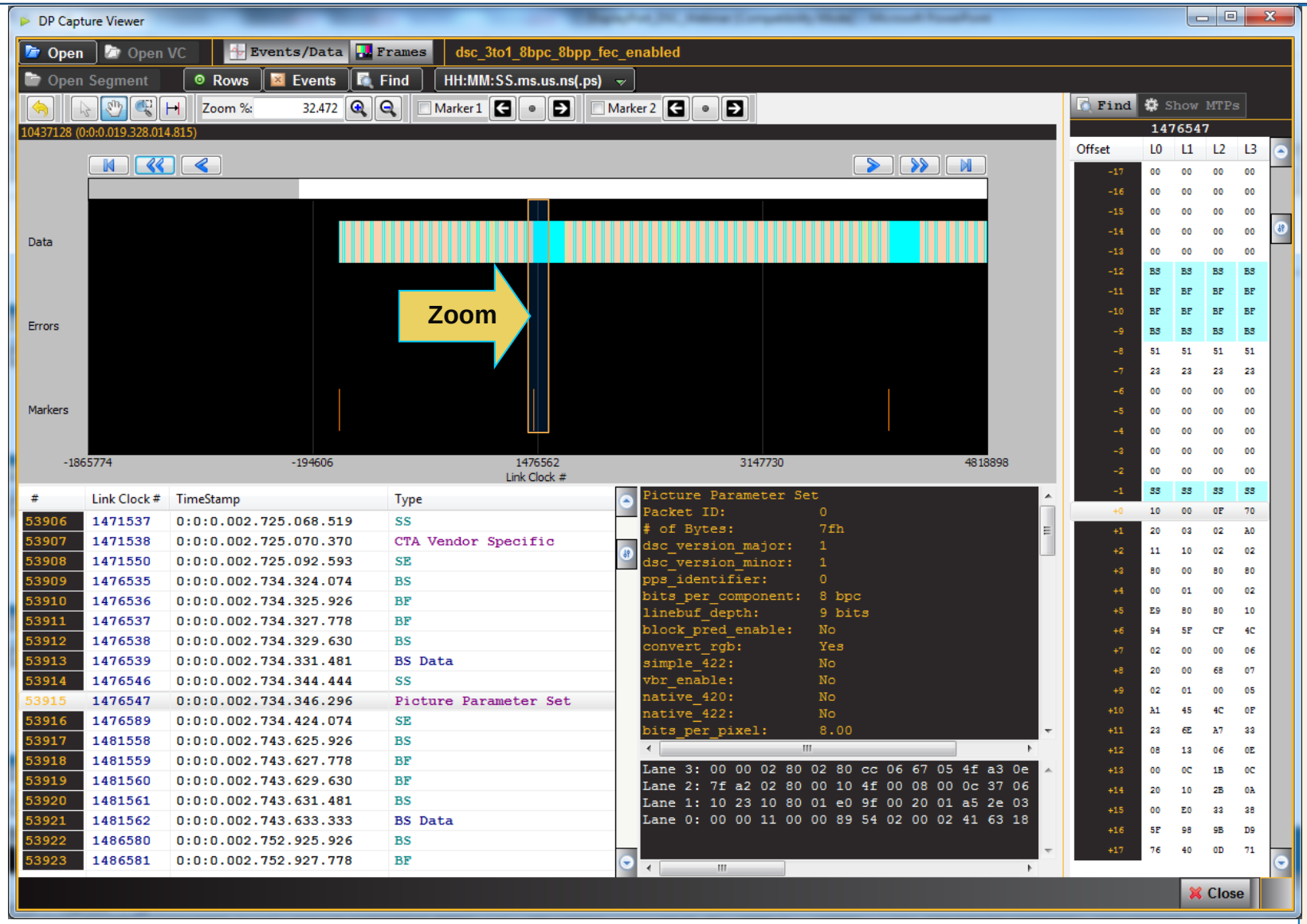
- VB-ID showing compression flag.
  - Zoomed in further showing end of line with EOC, Blanking Start packets and the VB-ID packet with the Compression Flag set.
  - Compression flag being set indicates to the decoder that it has to decode incoming compressed video data.

DisplayPort DSC Protocols
Main Stream Protocols
Picture Parameter Set (PPS)

Display Stream Compression – Picture Parameter Set

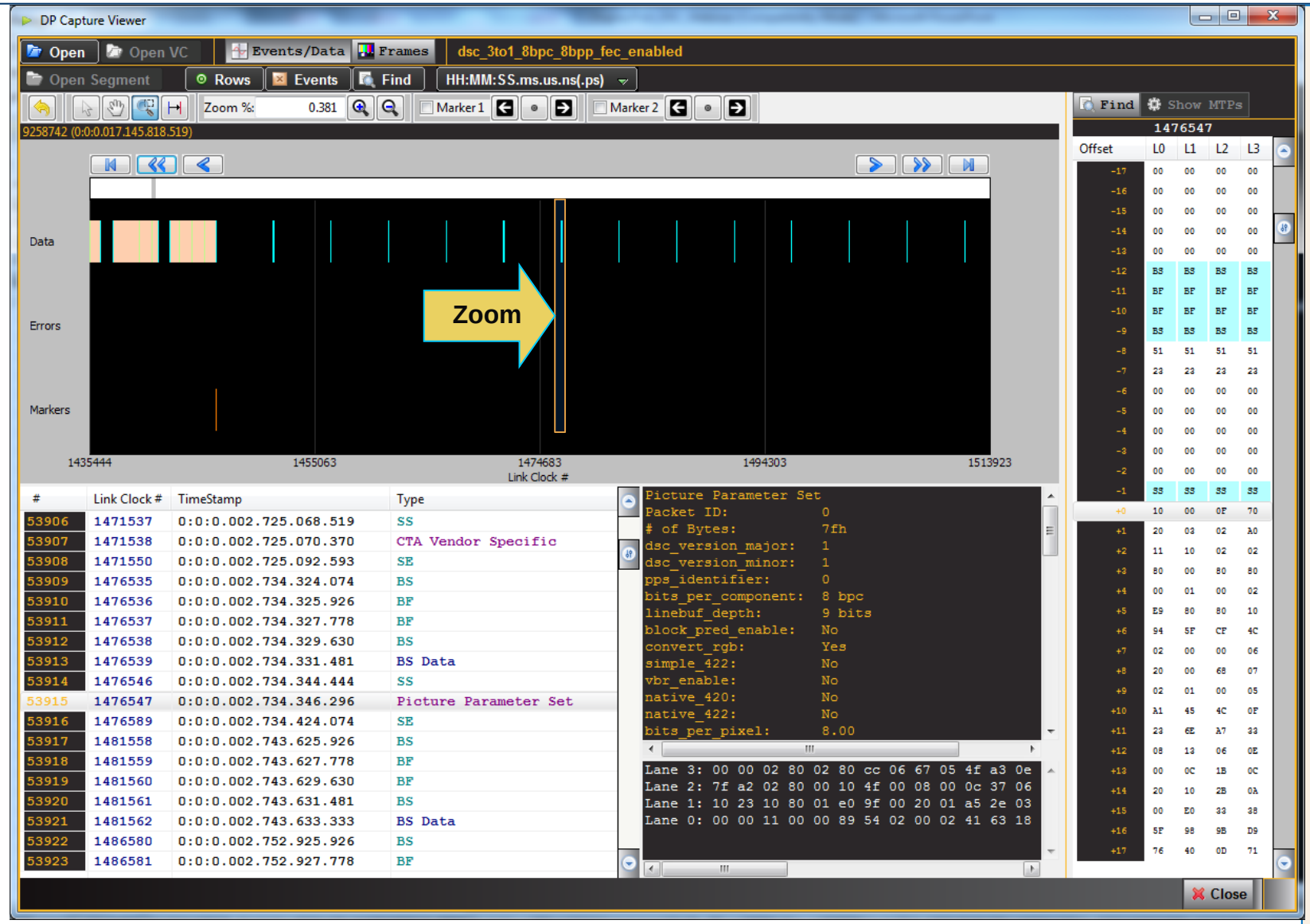
- Picture Parameter Set (PPS)
  - Source **sends PPS after** it receives an acknowledgement from the sink that the **Decompression Enable bit has been set** in the DPCD register.
  - The PPS is **transmitted over the main link during the vertical blanking** in a DisplayPort Secondary Data packet.
  - The parameter data that is transmitted in the **PPS is necessary to inform the sink how to decode the compressed data**.
  - Sink uses the last PPS transmitted before the Blanking Start (BS) symbol sequence of the scan line prior to where the active region starts.
  - Compression **parameters can be changed between compressed frames by transmitting a new PPS**. The PPS values apply to all subsequent frames.

Display Stream Compression – Picture Parameter Set



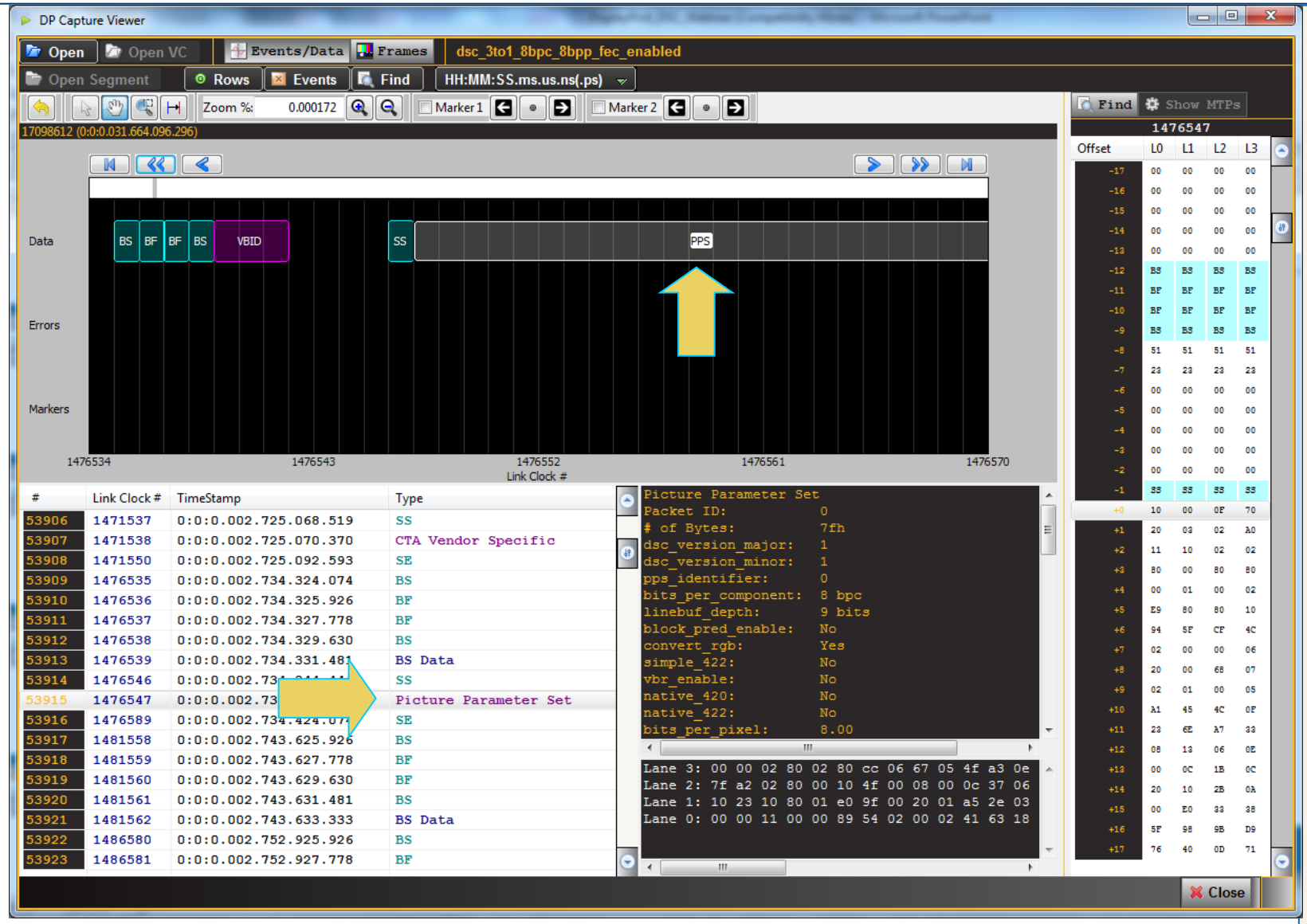
- Zoomed out view showing beginning of video and vertical blanking periods visible.

Display Stream Compression – Picture Parameter Set



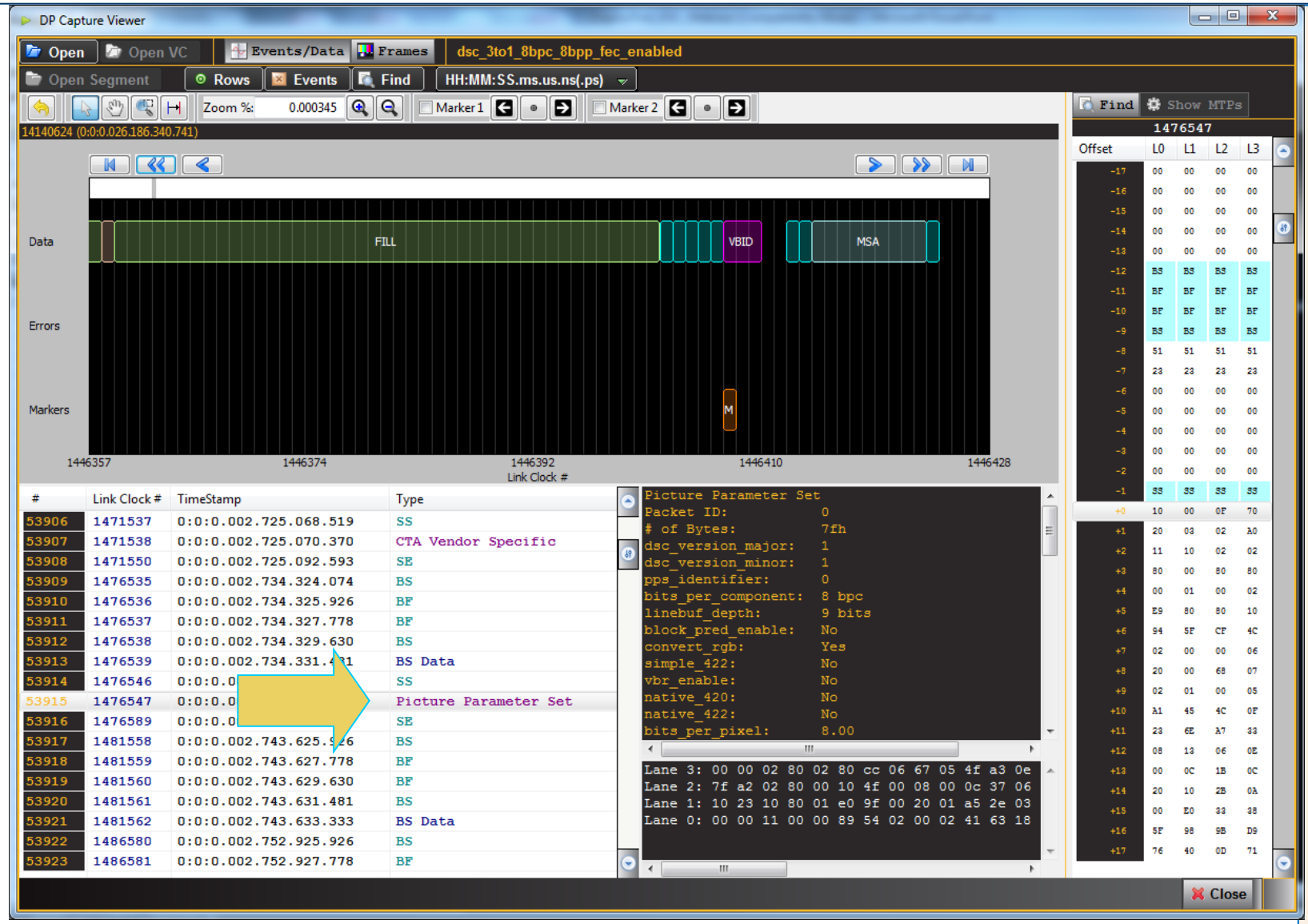
- Zoomed in to show end of a line of video with packets in the vertical blanking period shown.

Display Stream Compression – Picture Parameter Set



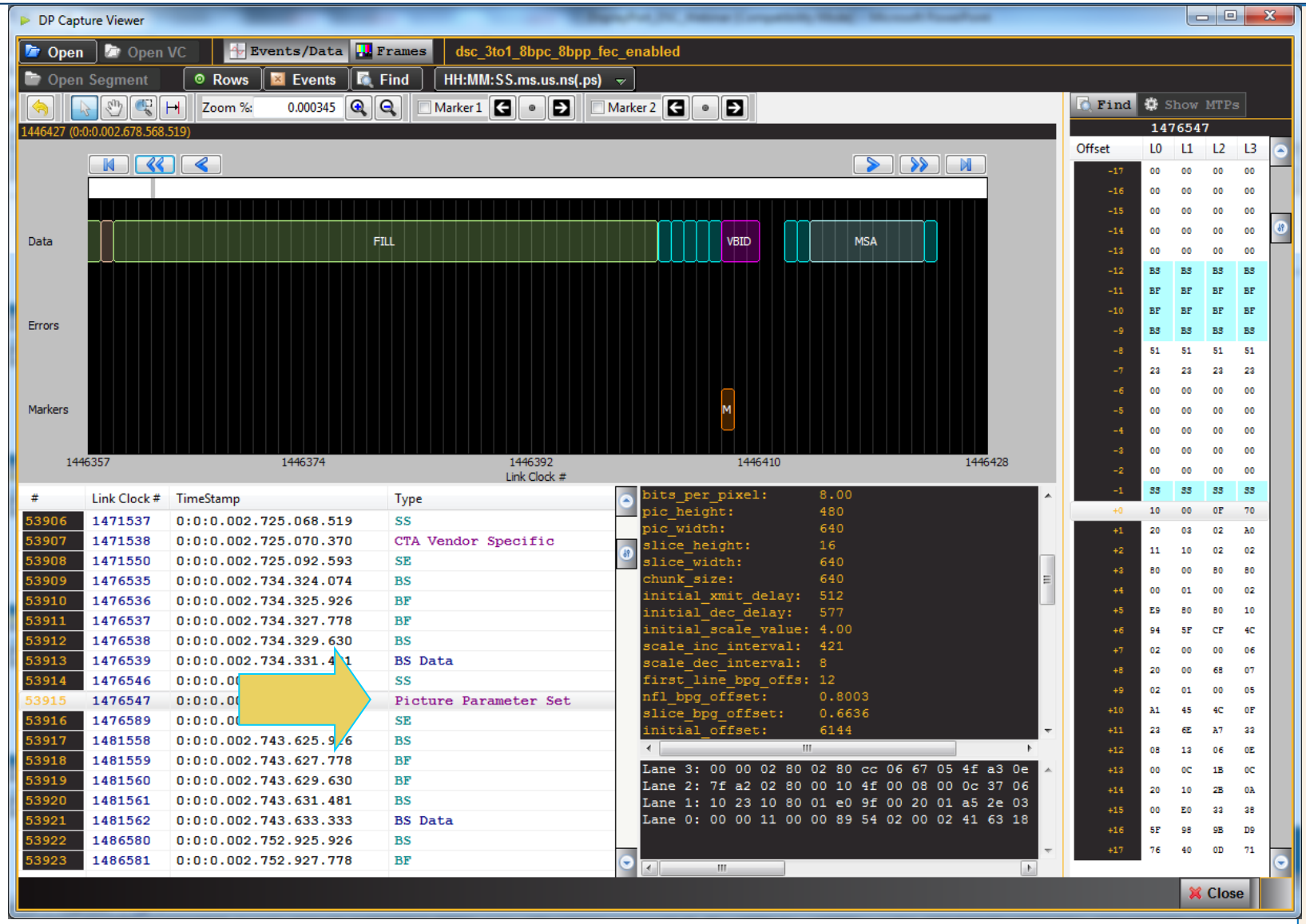
- Zoomed in to show Picture Parameter Set (PPS) packet.

Display Stream Compression – Picture Parameter Set



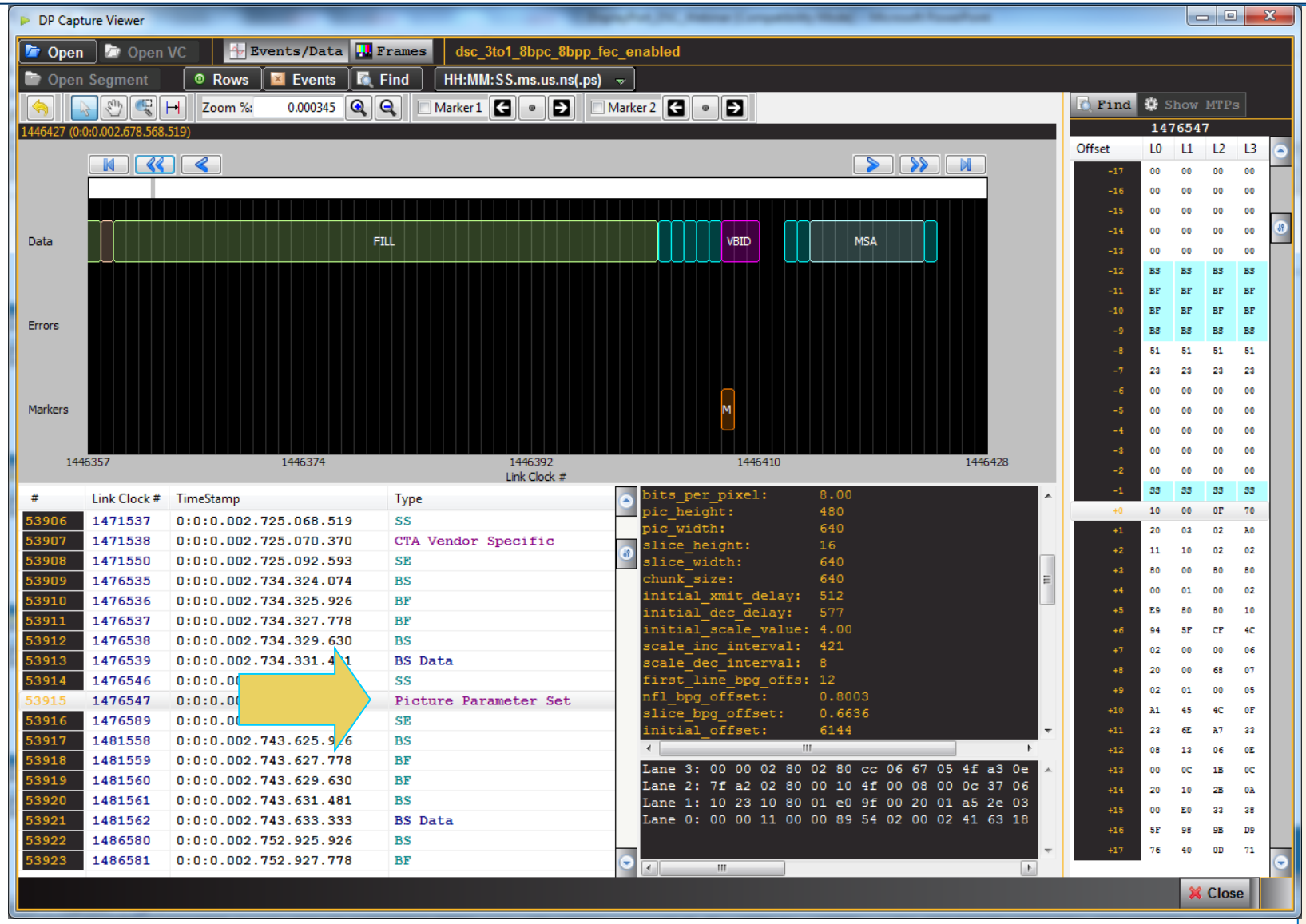
- Picture Parameter Set showing the following parameters:
  - DSC Version (major and minor).
  - PPS identifier – Indicates the packet type.
  - Bits per component – Number of **bits per component of the video**.
  - Line buffer depth.
  - Block prediction enable – **Indicates if there are any groups in the video frame (picture) that use the Block Prediction** method. If true this would mean that the decoder has to select between Block and MMAP prediction methods. Block prediction is an optional prediction method of a sink.
  - Convert RGB – **Indicates if the DSC encoder converted the video** from RGB to YCoCg.

Display Stream Compression – Picture Parameter Set



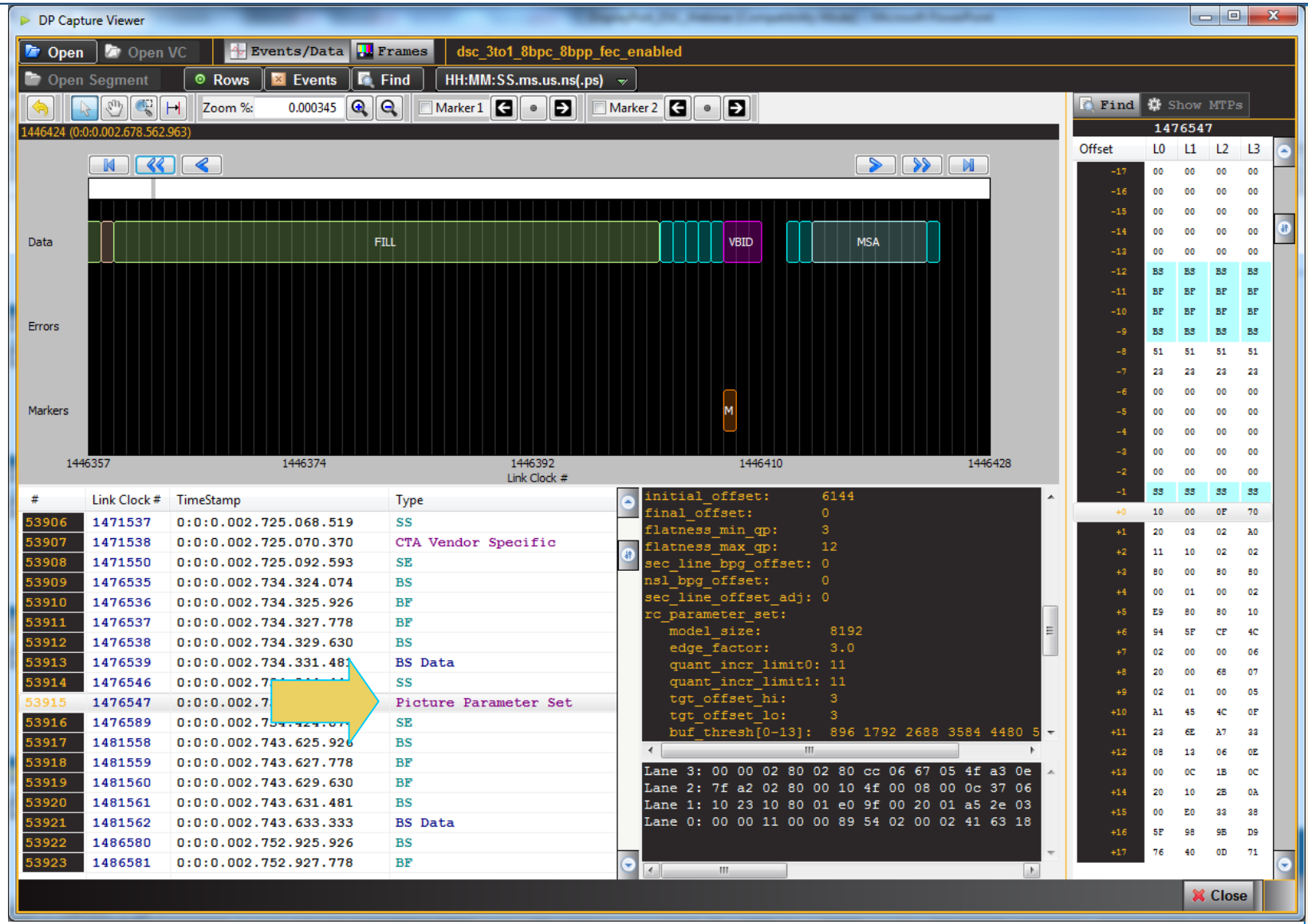
- Picture Parameter Set showing the following parameters:
  - Bits per Pixel – Specifies **the target bits per pixel** the encoder uses.
  - Picture Height – **Number of lines in the video frame** being encoded.
  - Picture Width – **Number of pixels per line** of the video frame being encoded.
  - Slice Height – **Number of lines in each Slice**.
  - Slice Width – **Number of pixels per line of each Slice**.
  - Chunk Size – **Number of bytes (pixels) in a chunk**. This is a function of the slice width.

Display Stream Compression – Picture Parameter Set



- Picture Parameter Set showing the following parameters:
  - Initial Transmitter Delay – Number of pixel times the encoder waits before transmitting data from its rate buffer.
  - Initial Decoder Delay – Number of pixel times the rate buffer in the decoder waits before decoding the compressed pixels.
  - First Line BPG offset – Specifies **the number of extra bits allocated to the first line of a slice to reduce artifacts**.

Display Stream Compression – Picture Parameter Set

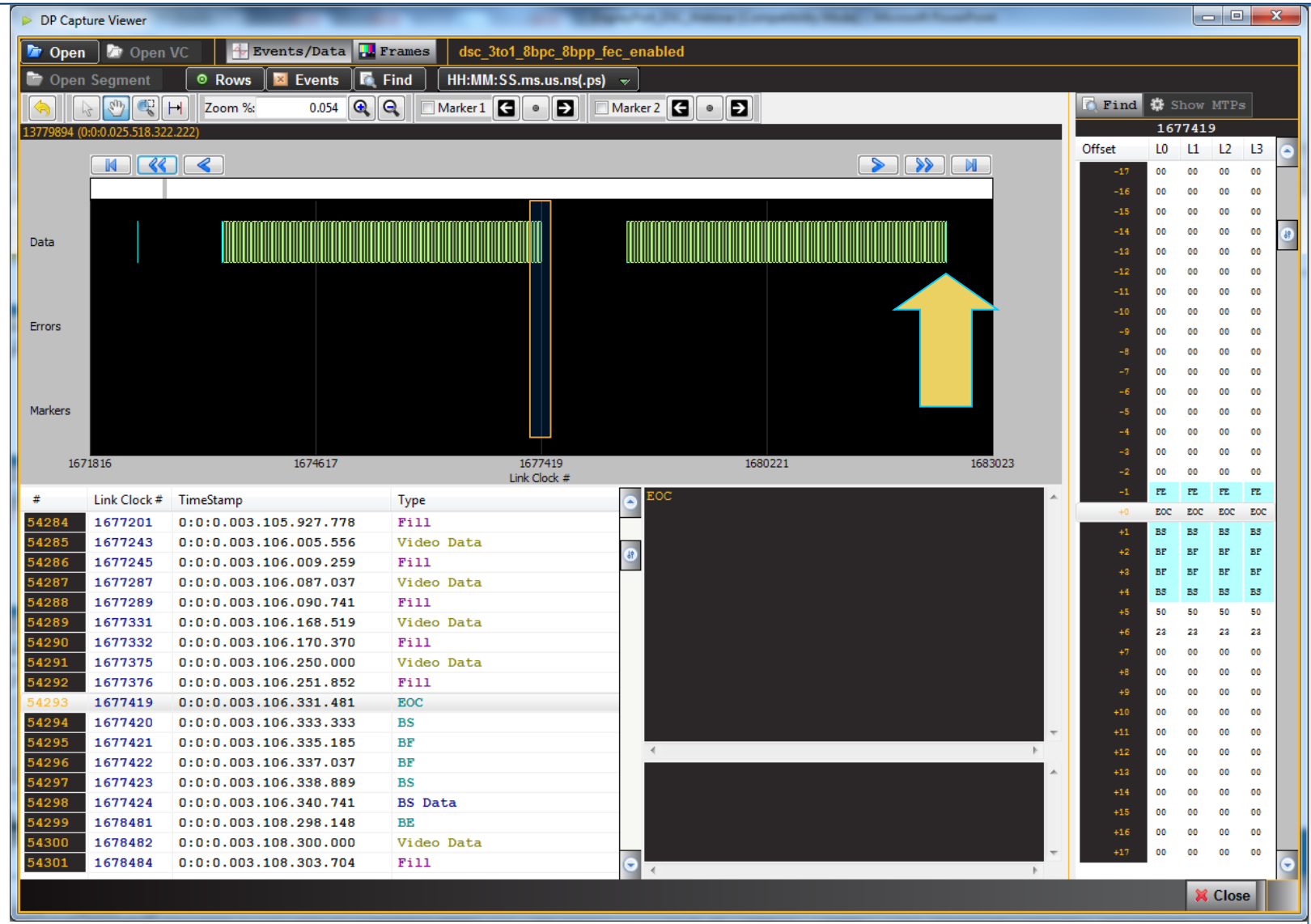


- Picture Parameter Set showing the following parameters:
  - Final Offset.
  - Flatness Minimum Up – Specifies the minimum Quantization Parameter (QP) that flatness is signaled and the flatness QP is made.
  - Flatness Maximum Down - Specifies the maximum Quantization Parameter (QP) that flatness is signaled and the flatness QP is made.

    Note: Flatness is signaled in the Luma substream.
  - Second Line BPG Offset.
  - NSL BPG Offset.
  - RC Parameters – Various parameters that control the Rate Controller.

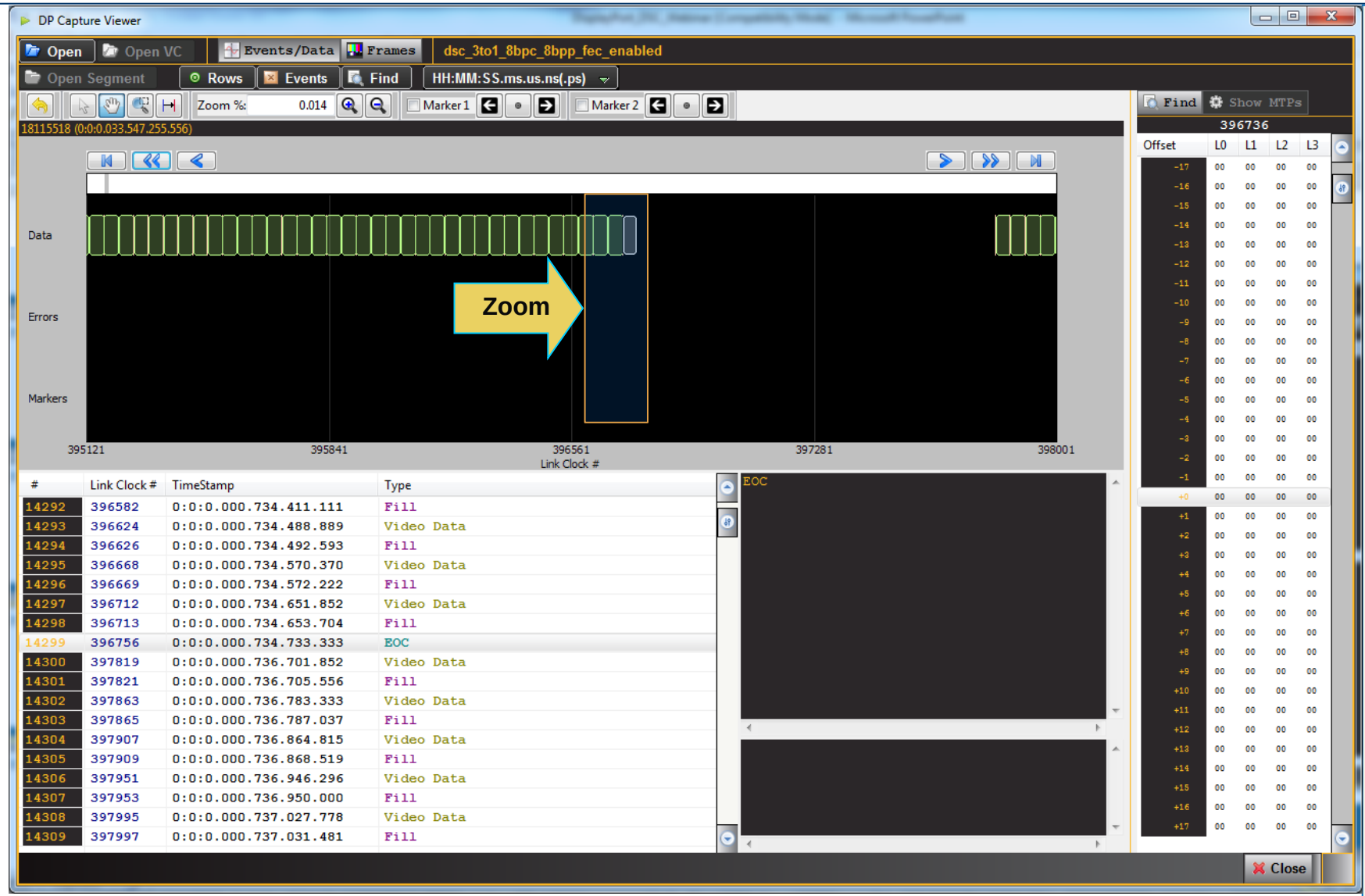
DisplayPort DSC Protocols
Main Stream Protocols
End of Chunk (EOC)

Display Stream Compression – End of Chunk



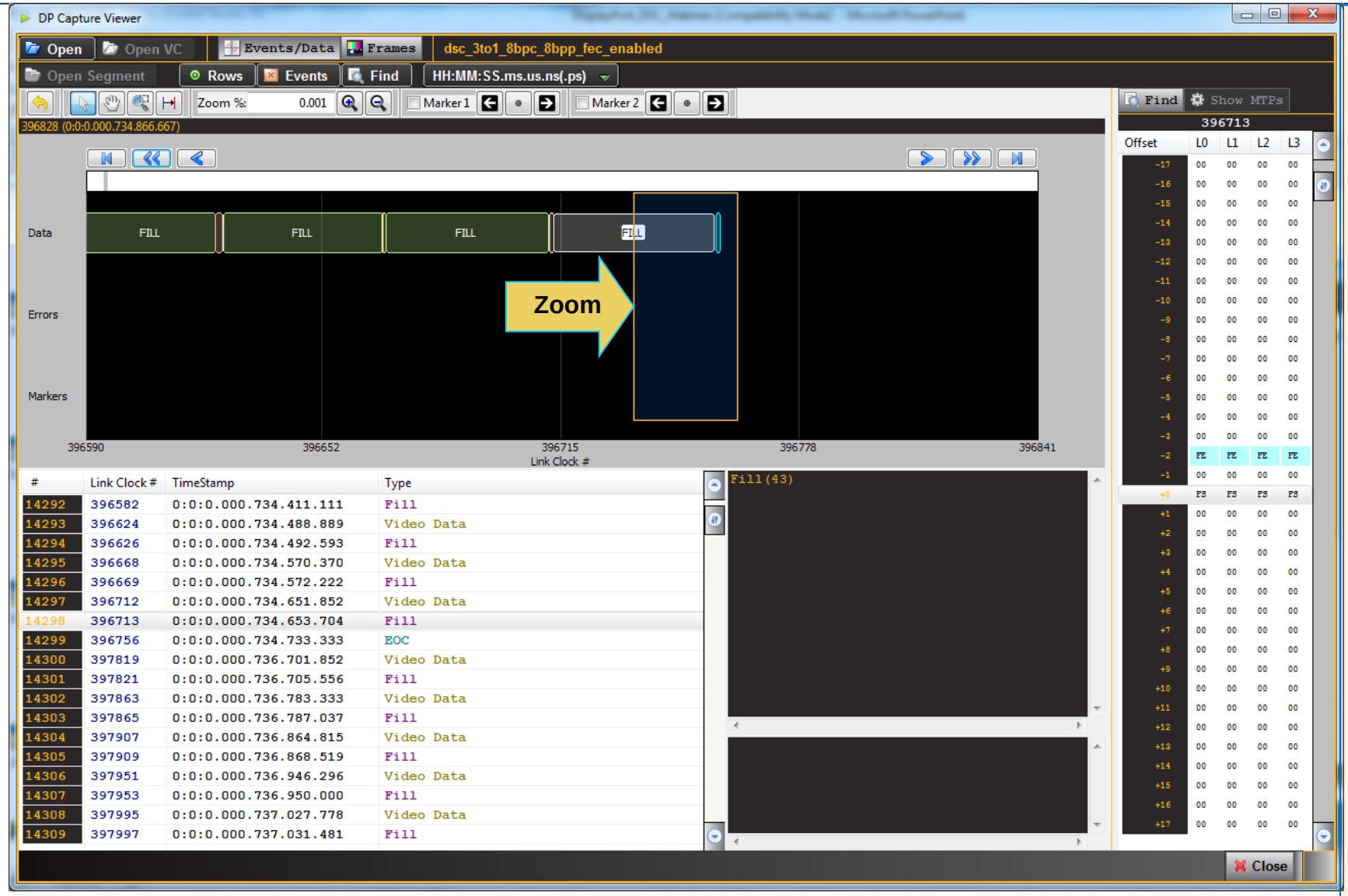
- End of Chunk packet
  - The DSC data stream is transported in units of Chunks.
  - A Chunk is the part of the bitstream that comprises the compressed data bytes.
  - Chunks are a line of video within a Slice.
  - Every Chunk is the same size.
  - An End of Chunk packet is placed at the end of each Chunk.

Display Stream Compression – End of Chunk



- End of Chunk packet
  - Zoomed in showing end of one line of video.
  - Showing the video fill characters.
  - Showing the horizontal blanking and the beginning of another line of video.
  - End of Chunk at the end of the video packets in the line.

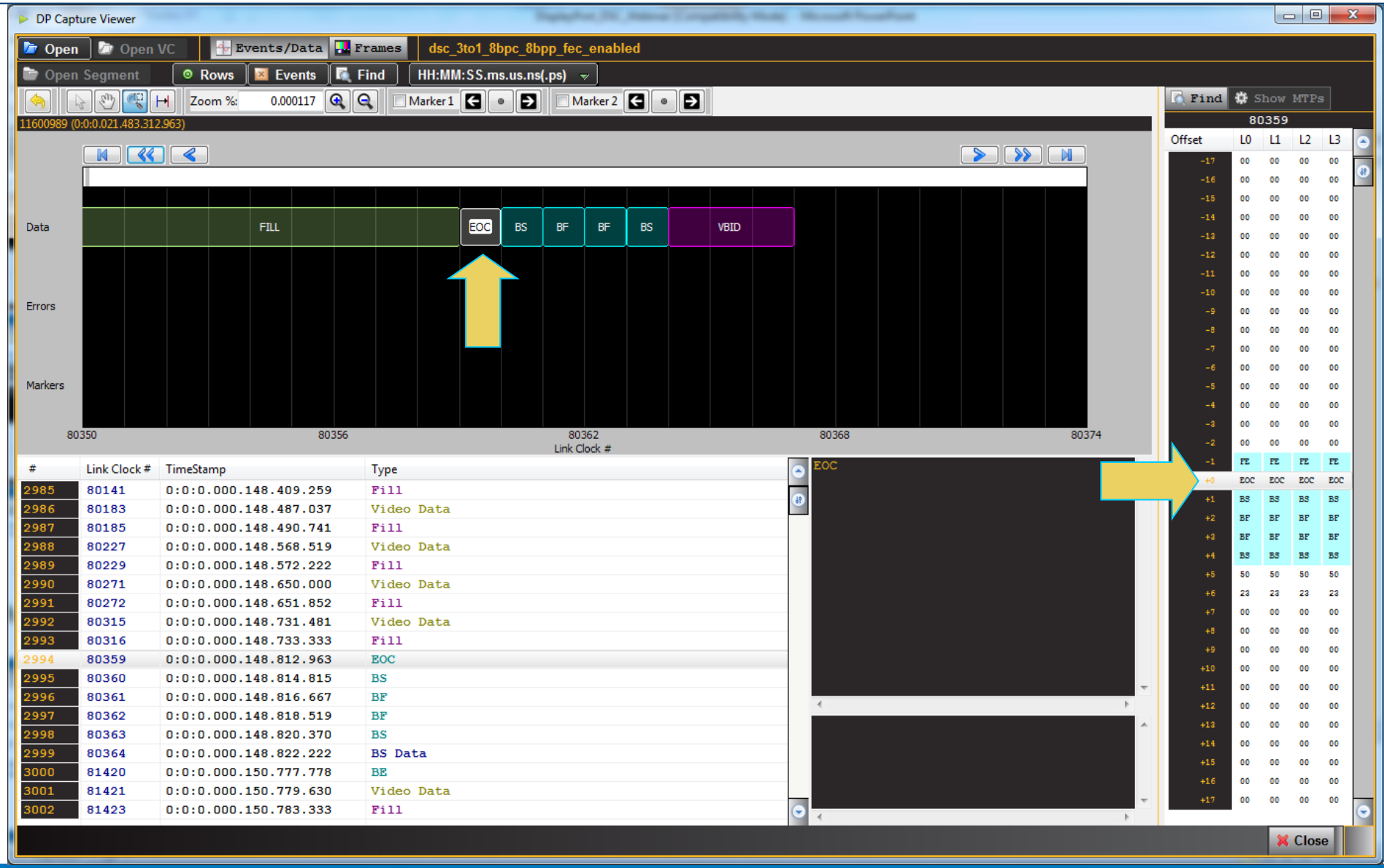
Display Stream Compression – End of Chunk



#	Link Clock #	TimeStamp	Type
14292	396582	0:0:0.000.734.411.111	Fill
14293	396624	0:0:0.000.734.488.889	Video Data
14294	396626	0:0:0.000.734.492.593	Fill
14295	396668	0:0:0.000.734.570.370	Video Data
14296	396669	0:0:0.000.734.572.222	Fill
14297	396712	0:0:0.000.734.651.852	Video Data
14298	396713	0:0:0.000.734.653.704	Fill
14299	396756	0:0:0.000.734.733.333	EOC
14300	397819	0:0:0.000.736.701.852	Video Data
14301	397821	0:0:0.000.736.705.556	Fill
14302	397863	0:0:0.000.736.783.333	Video Data
14303	397865	0:0:0.000.736.787.037	Fill
14304	397907	0:0:0.000.736.864.815	Video Data
14305	397909	0:0:0.000.736.868.519	Fill
14306	397951	0:0:0.000.736.946.296	Video Data
14307	397953	0:0:0.000.736.950.000	Fill
14308	397995	0:0:0.000.737.027.778	Video Data
14309	397997	0:0:0.000.737.031.481	Fill

- End of Chunk packet
  - Zoomed in further showing end of one line of video with video fill characters.
  - End of Chunk at the end of the video packets in the line.

Display Stream Compression – End of Chunk

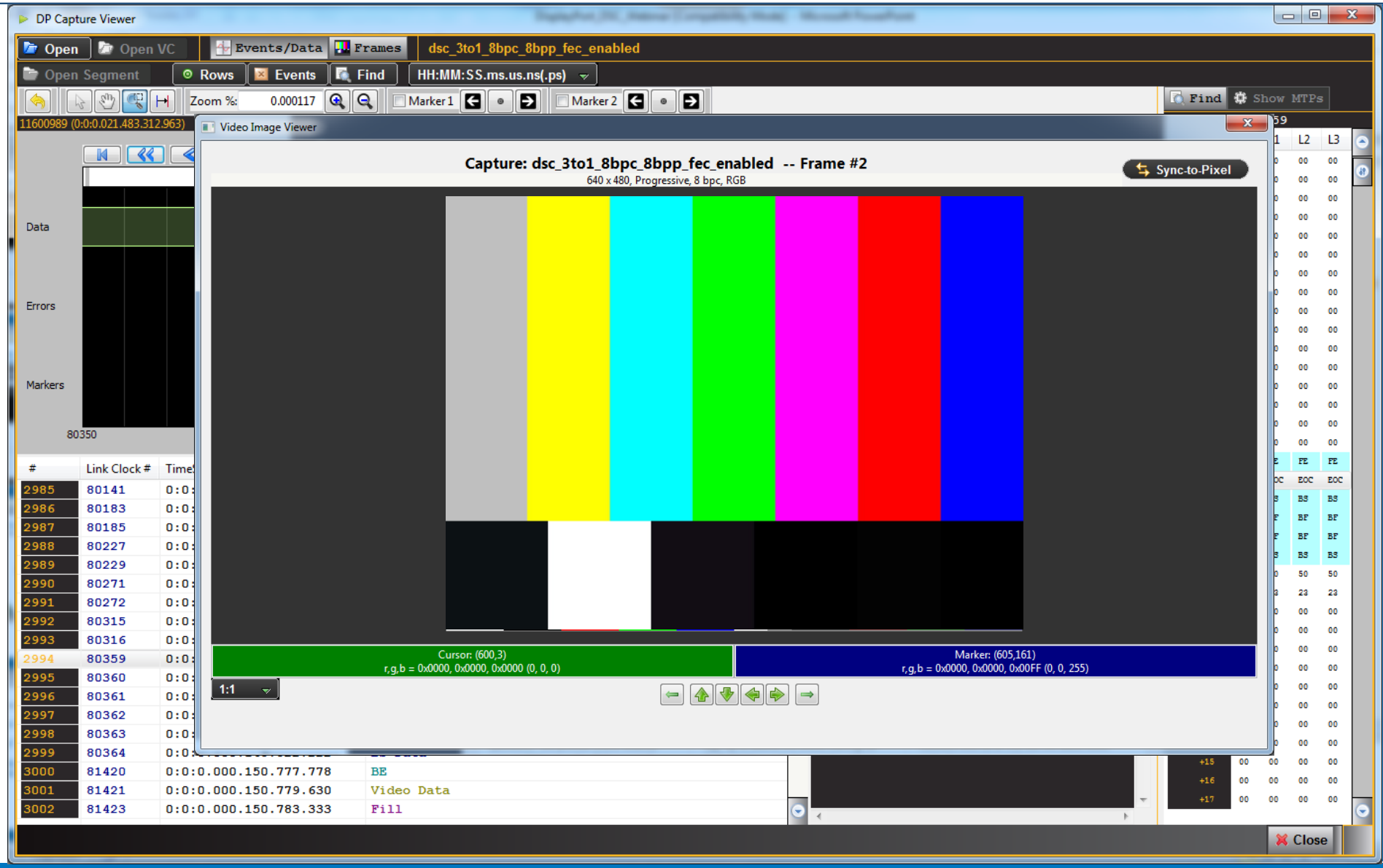


#	Link Clock #	TimeStamp	Type
2985	80141	0:0:0.000.148.409.259	Fill
2986	80183	0:0:0.000.148.487.037	Video Data
2987	80185	0:0:0.000.148.490.741	Fill
2988	80227	0:0:0.000.148.568.519	Video Data
2989	80229	0:0:0.000.148.572.222	Fill
2990	80271	0:0:0.000.148.650.000	Video Data
2991	80272	0:0:0.000.148.651.852	Fill
2992	80315	0:0:0.000.148.731.481	Video Data
2993	80316	0:0:0.000.148.733.333	Fill
2994	80359	0:0:0.000.148.812.963	EOC
2995	80360	0:0:0.000.148.814.815	BS
2996	80361	0:0:0.000.148.816.667	BF
2997	80362	0:0:0.000.148.818.519	BF
2998	80363	0:0:0.000.148.820.370	BS
2999	80364	0:0:0.000.148.822.222	BS Data
3000	81420	0:0:0.000.150.777.778	BE
3001	81421	0:0:0.000.150.779.630	Video Data
3002	81423	0:0:0.000.150.783.333	Fill

- End of Chunk packet
  - Zoomed in much further showing the end of a fill packet on the last transfer unit of a line.
  - There is an **End of Chunk packet on each lane**.

Note: This example is not typical. Normally, there would be more End of Chunk packets than there are lines of video because there are typically multiple slices across the horizontal picture frame.

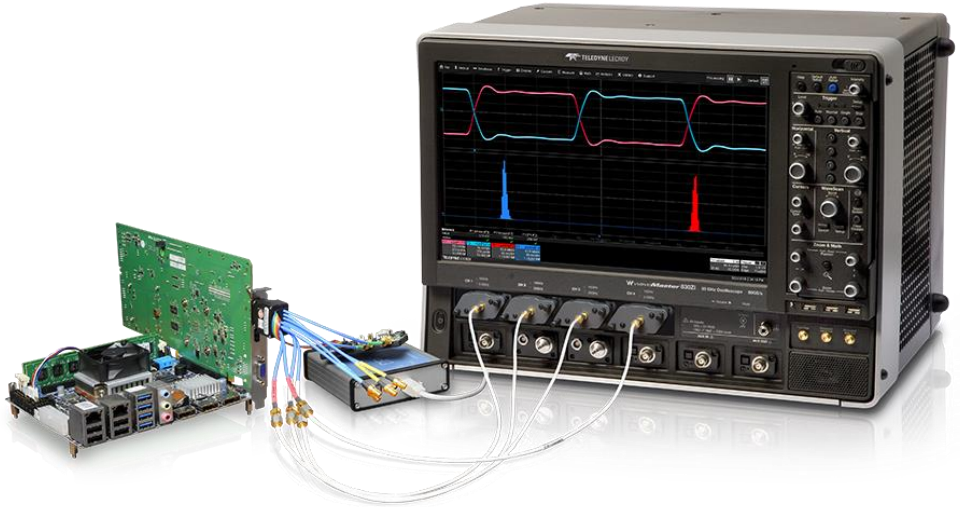
Display Stream Compression – Video Frame



- Video Frame
  - DSC strives for visually lossless compression.
  - This is a subjective measure.
  - Looking at the video frames can reveal DSC encoding and decoding artifacts.
  - Typically these would be more likely to occur at the edges of the video frame and the slices.

Teledyne LeCroy – DisplayPort Phy & Protocol Testing

DisplayPort Phy Compliance Testing at 8.1Gbps Link Rate



WaveMaster

DisplayPort Protocol Analyzer for DSC Streams at HBR3 8.1Gbps Link Rate

980B Platform w/ DisplayPort 1.4 Protocol Analyzer module

Thank you for attending

Please take the Brief 5 question survey at the end.

Note: We will provide you a link where you can obtain a recording and the slides in a couple days.

- We will be announcing additional webinars on the following topics in the coming months.
- Please share your thoughts on additional webinars of interest to you.

Please contact me, Neal Kendall at:
neal.kendall@teledyne.com
If you have any questions.