- "JPEG" joint working group of International Standardization Organization (ISO) & International Electrotechnical Commission (IEC)
- Standardized as ISO/IEC 21122
- It's neither JPEG nor JPEG 2000
- "XS" = "eXtra speed" & "eXtra small"
- Wavelet-based codec
- Low complexity – 4K 60p on i7 in real time
- Royalty required for use
- *Note there is no dash in the name of JPEG XS!*
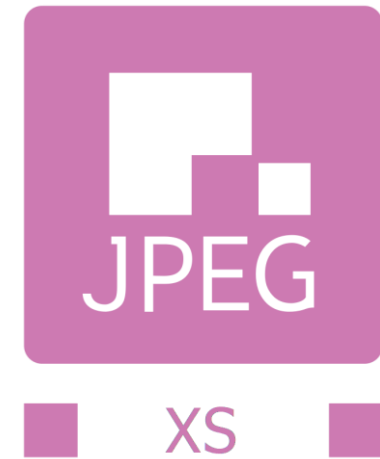
4 Key Defining Documents for JPEG XS in RTP

- ## ISO/IEC 21122-3
  - Specifies metadata "boxes"

- ## IETF RFC 9134
  - RTP payload format for JPEG XS

- ## SMPTE ST 2110-22
  - How CBR compressed video works in 2110 systems

- ## VSF TR-08
  - JPEG XS constraints for television signal interoperability

INTERNATIONAL STANDARD — ISO/IEC 21122-3

Information technology — JPEG XS low-latency lightweight image coding system —

Part 3: Transport and container formats

Stream: Internet Engineering Task Force (IETF)
RFC: 9134
Category: Standards Track
Published: October 2021
ISSN: 2070-1721
Authors: T. Bruylants — intoPIX, A. Descampe — UCLouvain, C. Damman — intoPIX, T. Richter — Fraunhofer IIS

RFC 9134
RTP Payload Format for ISO/IEC 21122 (JPEG XS)

SMPTE ST 2110-22:2019

SMPTE STANDARD

Professional Media Over Managed IP Networks: Constant Bit-Rate Compressed Video

VSF

Video Services Forum (VSF) Technical Recommendation TR-08
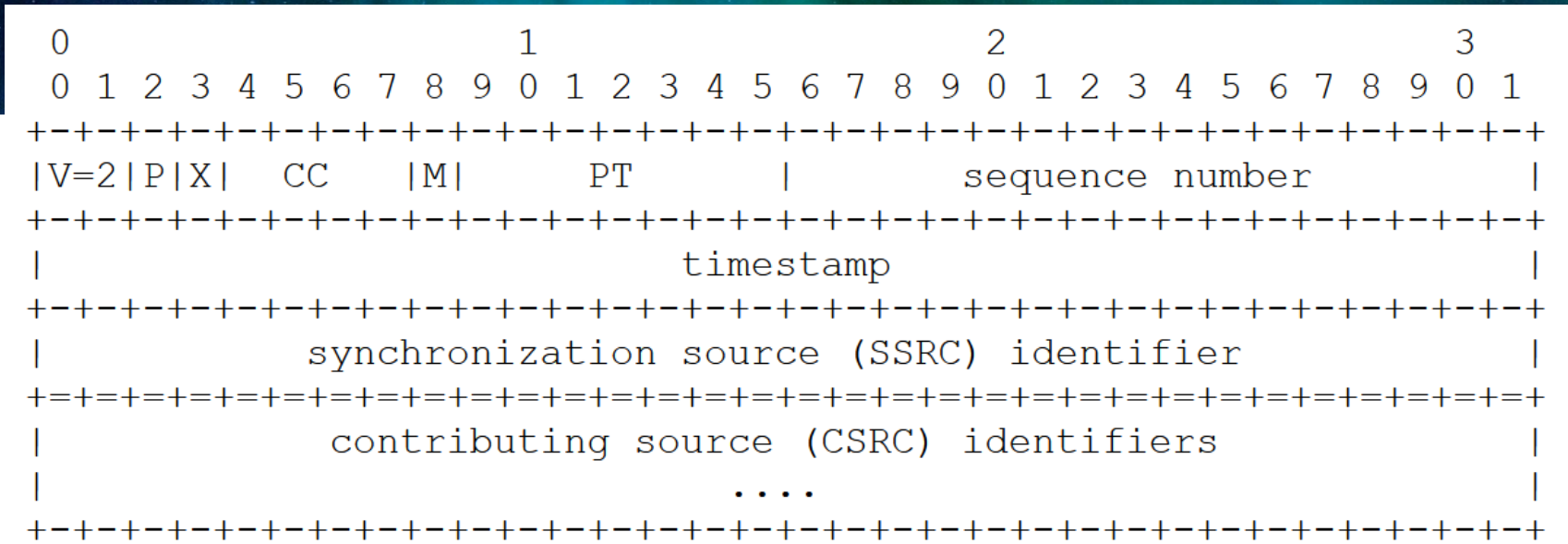
Transport of JPEG XS Video in ST 2110-22
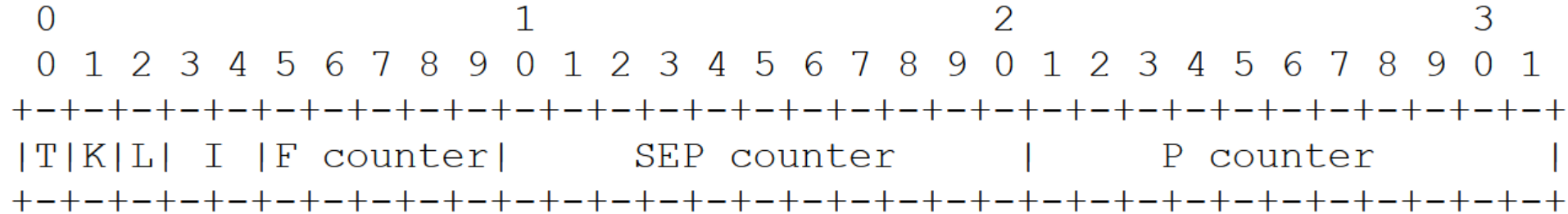
Important Vocabulary!

- ADU: Application Data Unit, spread across one or more...
- Packetization units, in "codestream packetization mode", a...
- JPEG XS picture segment, made up of:
  - Video Support Box
  - Color Support Box
  - JPEG XS codestream of one field/frame
- VSF TR-08 only allows codestream packetization mode
  - *I'll skip slice packetization mode...*

RFC 9134: RTP Header – no surprises

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|V=2|P|X|   CC  |M|     PT      |       sequence number         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           timestamp                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           synchronization source (SSRC) identifier            |
+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
|            contributing source (CSRC) identifiers             |
|                             ....                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- **V**ersion, **P**adding, e**X**tension, CSRC count (**CC**), sequence number, synchronization source & contributing source identifiers as per RFC 3550

- **M**arker Bit – last packet of field/frame

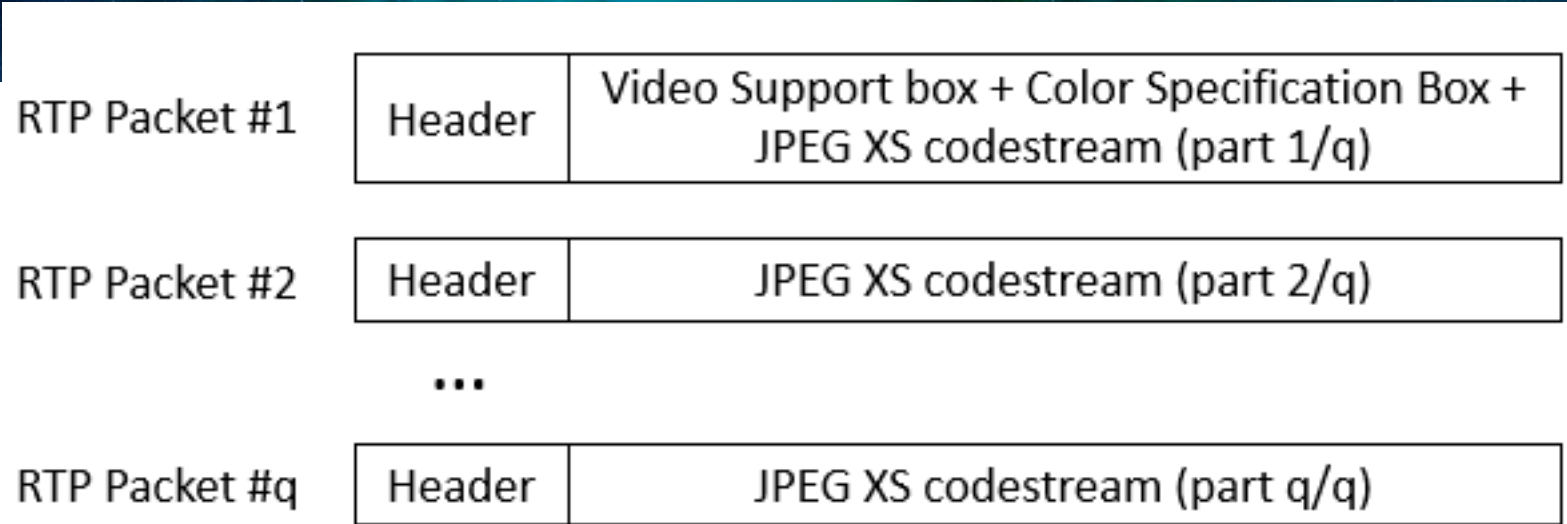- Timestamp – 90 kHz

RFC 9134: JPEG XS Payload Header

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|T|K|L| I |F counter|      SEP counter      |     P counter     |T|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- **T**ransmission mode: 1=sequentially, 0=may be out of order

- pac**K**etization mode: 0=codestream, 1=slice

- **L**ast: last packet of a packetization unit (in codestream mode, end of field/frame, and same as **M**arker bit)

- **I**nterlaced Information: 00=progressive, 10=first field, 11=second field

- **F**rame counter (modulo 32)

- Slice and Extended Packet (**SEP**) counter: resets when Packet counter resets & increments by 1 when Packet counter overruns

- **P**acket counter: Counts packets in packetization unit (for codestream mode, in the JPEG XS picture segment), modulo 2048

ISO/IEC 21122-3: Boxes

- "Derived from" atoms from ISO/IEC 14496-12 ISOBMFF / QuickTime, but specifically defined for JPEG XS

- LBox: 4 byte length field

- TBox: 4 byte box type
  - 'jpvs' (0x6A70 7673): **JPEG XS Video Support Box**
  - 'colr' (0x636F 6C72): **Color Specification Box**

- XLBox: 8 byte extended length field (if LBox=1)

- DBox: box contents

| RTP Packet #1 | Header | Video Support box + Color Specification Box + JPEG XS codestream (part 1/q) |
| RTP Packet #2 | Header | JPEG XS codestream (part 2/q) |

...

| RTP Packet #q | Header | JPEG XS codestream (part q/q) |

- Video Support (**VS**) Box
  - A "superbox", a box that contains other Boxes
  - Contains "video information"
  - e.g. frame rate, field coding, time code, profile/level
- Color Specification (**CS**) Box
  - e.g., color primaries, transfer characteristics, "full" range

- 'jpvi' (0x6A70 7669): **JPEG XS Video Information Box**
  - brat [32 bits]: max bitrate
  - frat [32 bits]: frame rate including interlace mode, numerator, denominator
  - schar [16 bits]: sample characteristics, bit depth, sampling
  - tcod [32 bits]: timecode HHMMSSFF
- 'jxpl' (0x6a78 706c): **JPEG XS Profile and Level Box**
  - Ppig [16 bits]: profile
  - Plev [16 bits]: level

ISO/IEC 21122-3: Video Support Box: optional sub-boxes

jpvi	jxpl	bmdm	dmon	jptp
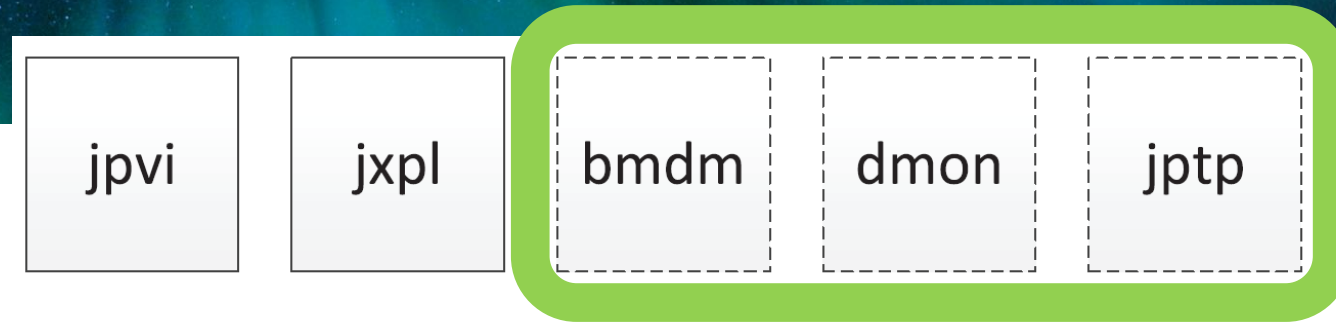
- **'bmdm' (0x626d 646d): Buffer Model Description Box**
  - Tmbd: buffer model from ISO/IEC 21122-2
  - Either the buffer model with limited transmission latency
  - ...or full use of decoder smoothing buffer (variable transmission latency)
  - # coefficient groups of horizontal & vertical blanking periods
- **'dmon' (0x646d 6f6e): Mastering Display Metadata Box**
  - SMPTE ST 2086 metadata
  - MCLL, MFALL as per CTA 861-G
- **'jptp' (0x646d7370): JPEG XS Video Transport Parameter box**
  - Suggestions to decoder: # slices assigned to processing units, #parallel decoding units, size of packet reordering buffer

ISO/IEC 21122-3: Color Specification Box
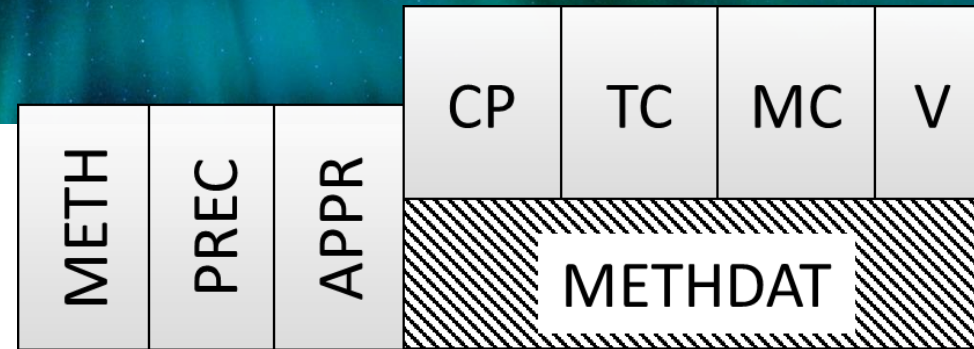
- 'colr' (0x636F 6C72): **Color Specification Box**
  - METH [8 bits]: 5=Coding Independent Code Points (CICP) of Rec. ITU-T H.273
  - PREC [8 bits]: Precedence, undefined, should =0
  - APPR [8 bits]: Colorspace approximation, currently =0

- METHDAT: Method data for CICP
  - CP [16 bits]: Color primaries
  - TC [16 bits]: Transfer characteristics
  - MC [16 bits]: Matrix coefficients
  - V [8 bits]: Video Full Range Flag (1=full range)

Color Specification Box Commonly Used METHDAT (from VSF TR-08)

Color Space	Color primaries code	Transfer characteristics code	Matrix coefficients code	Video full range flag	Notes
Rec. ITU-R BT.709-6	1	1	1	0	BT 709 SDR
Rec. ITU-R BT.2100-2	9	16	9 (Y'CbCr)	0	PQ HDR with BT 2020
Rec. ITU-R BT.2100-2	9	18	9 (Y'CbCr)	0	HLG HDR with BT 2020

ISO/IEC 21122-1: JPEG XS Codestream

- **Markers**
  - Identify structural parts of codestream
- **Marker segments**
  - Markers followed by length field and data parameters
- **Entropy coded data**
  - Wavelet coefficients that have been entropy coded
- **Precincts**
  - Entropy coded data of wavelet coefficients contributing to spatial region of the image
- **Slices**
  - integral number of precincts over the full width of the image.
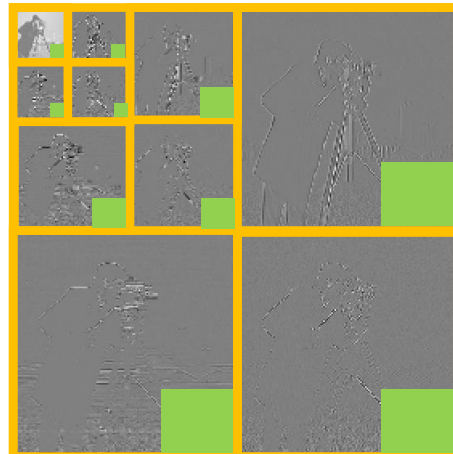
Image   Precinct   Slice
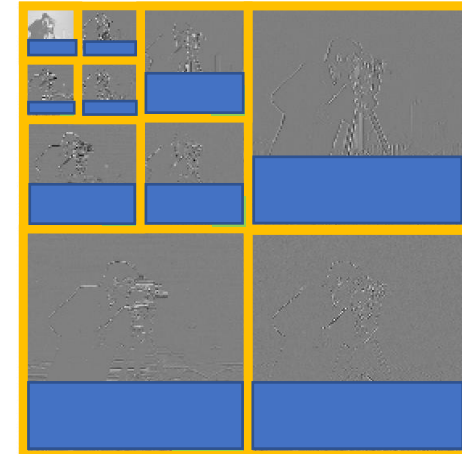
JPEG XS Codestream Syntax

Syntax Element	Syntax Type	Code (if marker)
Start of Codestream (SOC)	marker	0xff10
Capability Marker	marker segment	0xff50
Picture Header	marker segment	0xff12
Component Table	marker segment	0xff13
Weights Table	marker segment	0xff14
Extension Marker	marker segment	0xff15
Loop over Slices {		
Slice Header	marker segment	0xff20
Loop over Precincts {		
Precinct Header	entropy coded data	
Loop over Packets {		
Packet Header	entropy coded data	
Packet Body }	entropy coded data	
Fill()		
}} End of Codesteam (EOC)	marker	0xff11

IP SHOWCASE

ST 2110

Emmy® Award Winning

ST 2110-22

Use CBR RTP Payload defined by IETF

I E T F®

RFC 9134

RTP Payload Format for ISO/IEC 21122

+

JPEG

XS

=

ST 2110-22 with JPEG XS

VSF TR-08 Constraints

- Codestream Packetization Mode

- JPEG XS profile "High444.12"

- 5 horizontal & 2 vertical wavelet transforms

- Only uniform quantizer

- 4 bpp min & 1.5 bpp max compression

- # bytes in Payload Data multiple of 8 bytes

- Senders/receivers must support "configurations"
  - Combinations of Conformance Level & Capability Set
  - Includes audio & video
  - Intra-facility, interfacility, and intra-campus IPMX Capability Sets

Important Note

- RFC 9134 took 3 ½ years to develop

- Internet-draft versions significantly different than RFC

- Fielded devices may use -0 or -3 version of I-D
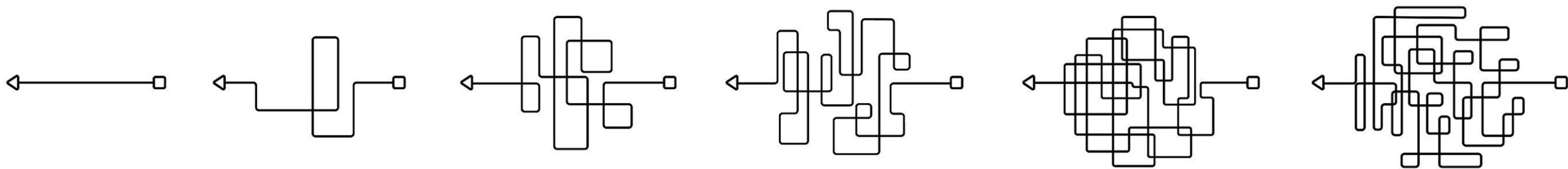
JPEG XS RTP Wireshark Dissectors from intoPIX

Available for free from:
https://www.intopix.com/blogs/post/Deep-dive-into-SMPTE-ST2110-22-with-Wireshark-Dissector

JPEG XS Interop @ Amazon Studios

- March 31/April 1, 2022

- 11 vendors, >200 different interoperation tests

- Encoders, decoders, multiviewers, camera

- On-prem & AWS Elemental cloud

- Interlaced HD, progressive HD, and UHD video stream formats.

- Appear, Evertz, Imagine Communications, Grass Valley, Matrox, Media Links, Nevion, Riedel, Sencore, TAGvs
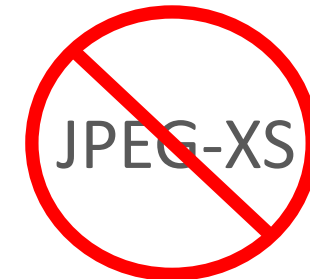
What about discovery and control?

- NMOS is the registration and discovery and connection management layer for many ST 2110 systems
- NMOS easily works with new formats, not just uncompressed video/audio
- The AMWA has a final draft of BCP-006-01 "NMOS With JPEG XS" – https://specs.amwa.tv/bcp-006-01
- BCP-006-01 specifies how the capabilities of JPEG XS Media Nodes are described in IS-04 and IS-05 to ensure Controllers can identify and connect compatible senders and receivers
- Final step before elevation to AMWA Specification is to demonstrate interop and an automated test suite, targeting Q4 2022
  - New participants welcome to join in! Contact garethsb@nvidia.com

Conclusions

- JPEG XS – software friendly, high-quality, low-latency codec, great for on-prem or the cloud

- Several different documents must be read to understand the carriage of JPEG XS over RTP/IP

- Interop event proved multi-vendor interoperation of JPEG XS

- Broadcast industry is now actively using JPEG XS over IP, and we've got Wireshark dissectors to help!

- *Note there is no dash in the name of JPEG XS!*   JPEG-XS

Any Questions?