SMPTE Standards Webcast Series
SMPTE Professional Development Academy – Enabling Global Education

SMPTE ST 2094 and Dynamic Metadata

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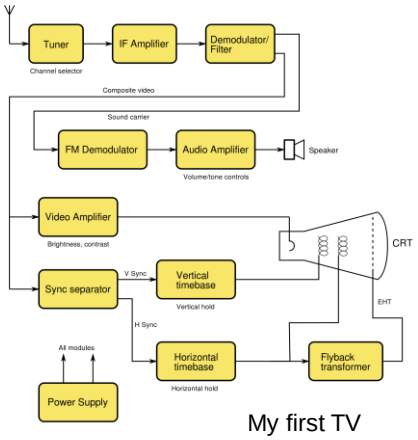

My first TV

SMPTE Standards Update Webcasts

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- Series of quarterly 1-hour online (this is is 90 minutes), interactive webcasts covering select SMPTE standards
- Free to everyone
- Sessions are recorded for on-demand viewing convenience SMPTE.ORG and YouTube

Your Host

Professional Development Academy
Enabling Global Education

- **Joel E. Welch**
- Director of Education
- SMPTE

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Today's Guest Speaker

Professional Development Academy
Enabling Global Education

Lars Borg

Principal Scientist in
Digital Video and
Audio Engineering

Adobe

What?

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- HDR vs SDR
- Tone mapping
- HDR systems & tone mapping options
- Dynamic metadata

High Dynamic Range - Slim, Wide, Tall Volumes

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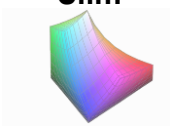
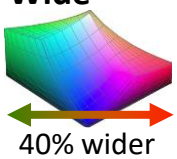
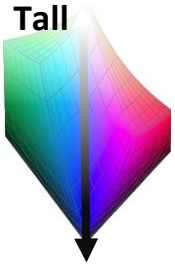
TV System	*ITU Std*	*Image Size*	*Color Volume*
HD	**BT.709**	1920 x 1080 "2K"	Slim (**SDR**)
UHD 1	**BT.2020**	3840 x 2160 "4K"	Slim **or** Wide Color Gamut (**WCG**)
UHD 2	**BT.2020**	7680 x 4320 "8K"	Wide Color Gamut (**WCG**)
HDR	**BT.2100**	2K, 4K, 8K	Wide & Tall (**HDR**)





40% wider
Saturated colors



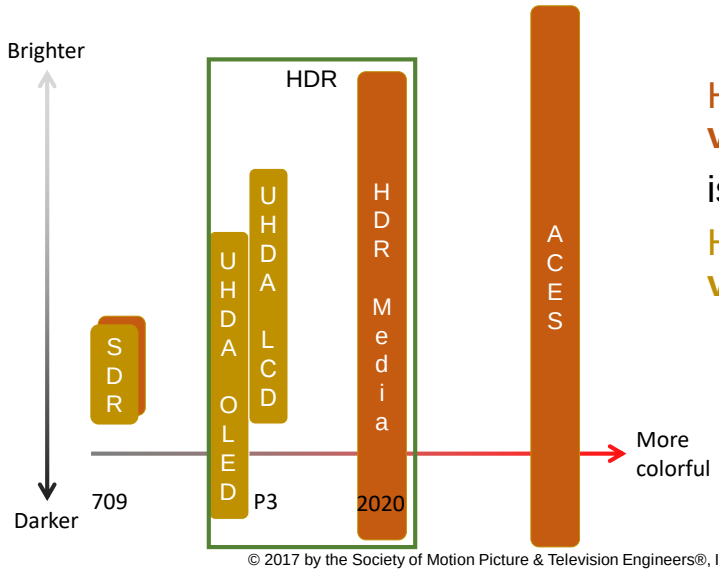
High dynamic range

10-100x brighter peaks

100x darker than SDR ref

Wide Color Gamut makes deeper colors available

HDR brightness ranges and gamuts



HDR **media color volume**

is much larger than

HDR **display color volume**

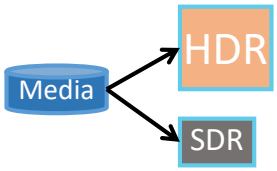
Comparing SDR and HDR system details

Feature	***Old: SDR TV (Rec. 709, Rec. 601)***	***New: HDR TV (Rec. 2100)***
Max Resolution	1920 x 1080	7680 x 4320
Max Frame rate	60 fps	120 fps
Bit depth	8 or 10	10 or 12
Media Color Volume	Small (Rec. 709)	Wide (2020) and Tall (10,000 nits)
Display Color Gamut	Small (Rec. 709)	Medium (P3)
Display Peak Brightness	typically 300 nits, studio mon. 100 nits	At least 1,000 nits (LCD), 530 nits (OLED)
Transfer Characteristics	BT.1886 Gamma 2.4	PQ curve or HLG curve
Color models	RGB, YCbCr	+ ICtCp (Constant Intensity)
Compression	MPEG-2, AVC, J2K	AVC, J2K, HEVC
Color Volume Metadata	None	None, HDR10, or ST2094

Which grade first? You pick!

- HDR first
  - Most exciting version first
  - SDR grades from HDR version
  - Best for real-time workflows

- SDR first
  - Do the money-making (2017!) version first
  - HDR uses SDR master files, not 10-bit SDR distribution images



- HDR and SDR independently graded from master media
  - Very expensive (double effort)
  - Highest quality for both versions

- Some colorists find it difficult to grade both HDR and SDR!

Why do I need tone mapping?

Clipped highlights and shadows

Compressed highlights and shadows

What are my HDR signal options?

Standout Experience

SDR ?

Simplicity

DMCVT Dynamic Metadata for Color Volume Transform

HDR10 Static Metadata (Ultra HD Blu-ray)

PQ Perceptual Quantizer (ST 2084)
No metadata (UHD Alliance Premium)

HLG Hybrid Log Gamma
No metadata

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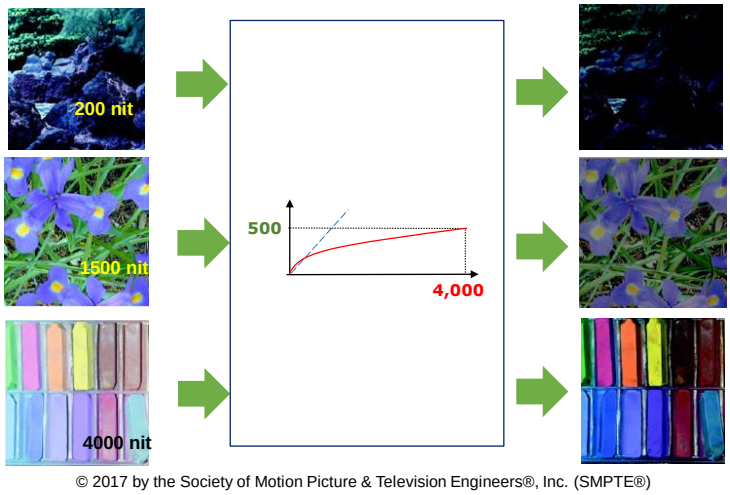
Static Tone Mapping – HDR10

Optimized **only for the brightest scene** in the contents



Illustrations courtesy of YT Kim, Samsung

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Dynamic Tone Mapping – DMCVT

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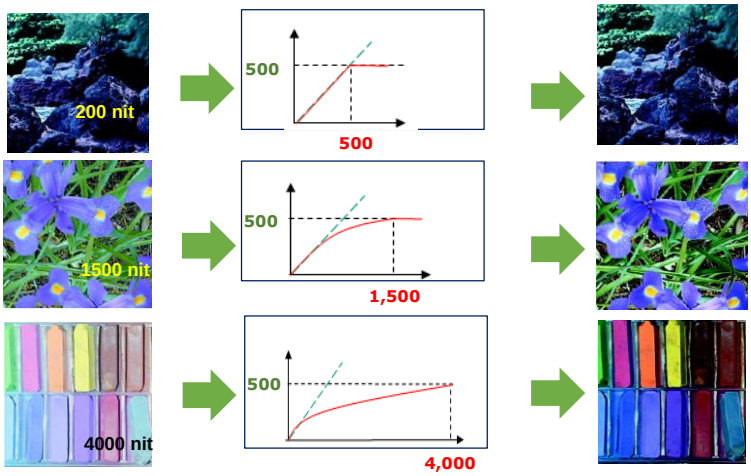
Optimizes each scene



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Dynamic Tone Mapping can preserve SDR image quality

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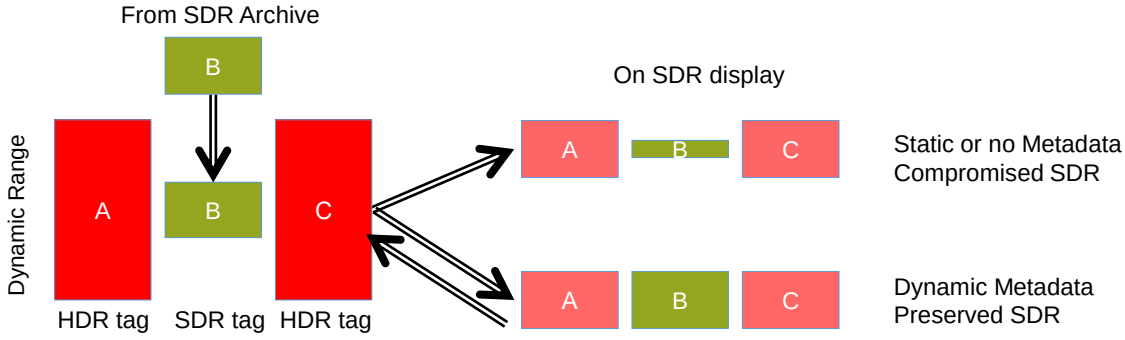
- SDR footage inserted in HDR program needs special handling when converting to SDR
  - To preserve original SDR imagery and prevent loss of image quality
- Dynamic Metadata provides the info



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ST 2094 — Dynamic Metadata for Color Volume Transforms (DMCVT)

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- Color transforms optimized for each scene, and each display
- SMPTE ST 2094, in six parts, published 2016
  - Carried in HEVC SEI, ETSI TS 103 433, CTA 861-G
- Standardizes HDR color transform technologies from
  - Dolby (Parametric Tone Mapping)
  - Philips (Parameter-based Color Volume Reconstruction)
  - Technicolor (Reference-based Color Volume Remapping)
  - Samsung (Scene-based Color Volume Mapping)
  - And 80 other participating companies

DOLBY
PHILIPS
SAMSUNG
technicolor

ST 2094 Document Structure

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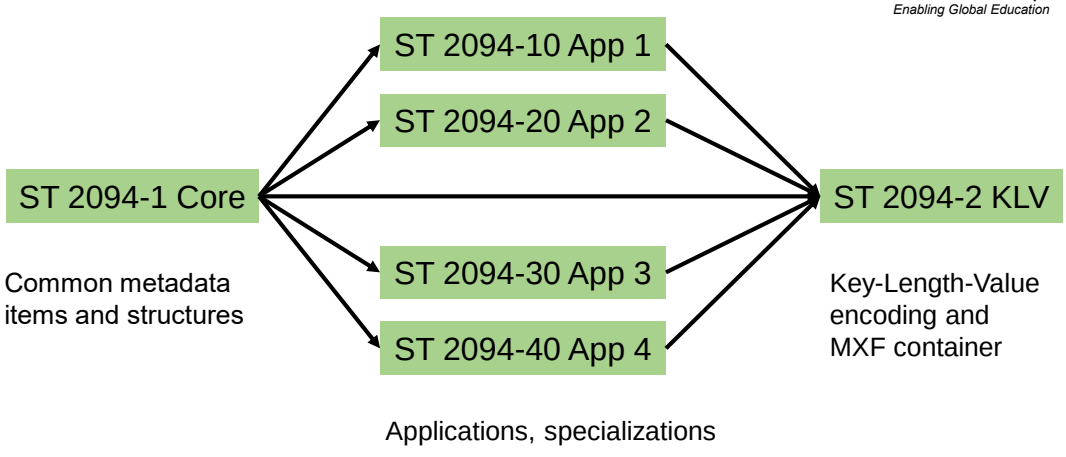
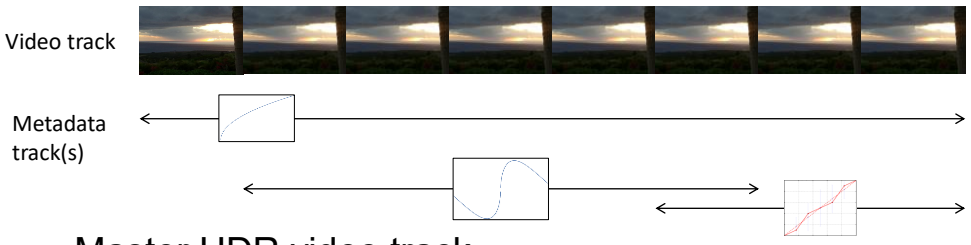


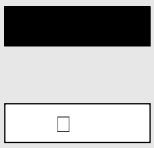
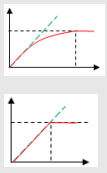
Parallel metadata track(s)



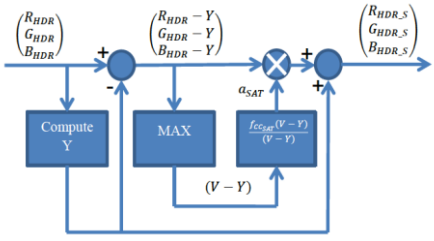
- Master HDR video track
- Metadata tracks carry supplementary color grading information
- Select where to apply the metadata
  - By time, window, target display

The ST 2094 metadata set

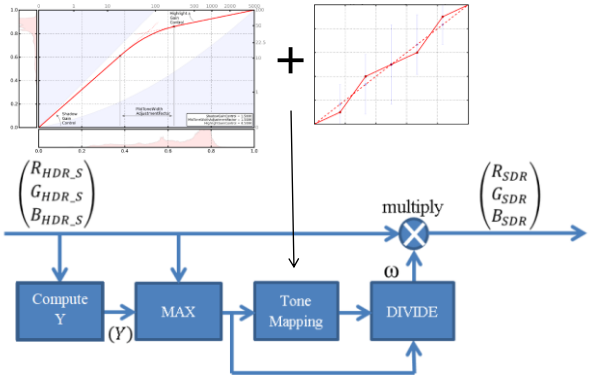
Each ST 2094 metadata set specifies one of each of:

Method	***Target Display***	***Time Interval***	***Window***	***Transform***
Which?	For what display?	When?	Where?	What to do?
	Rec. 709 Rec. 2020 UHDA OLED	⇤ □□□□□□ ⇥ ⇤ □□□ ⇥		
App # *Version #*	*Color Volume: RGB primaries, WP, max/min*	*Start and duration*	*Pixel coordinates Baseline = full screen*	*4 flavors of parameter sets*

App. 2 — Color Transform in Parameter-based Color Volume Reconstruction (Philips)



Saturation-driven Desaturation



Luminance-based Tone Mapping

Lots of math for calculating the curves

$$TMO(x) = \begin{cases} SGC \times x, & 0 \le x \le x_{SGC} \\ ax^2 + bx + c, & x_{SGC} < x < x_{HGC} \\ HGC \times x + 1 - HGC, & x_{HGC} \le x \le 1 \end{cases} \quad (1)$$

$$a = \begin{cases} 0, & para = 0 \\ -0.5 \times \frac{SGC - HGC}{para}, & otherwise \end{cases} \quad (2)$$

$$b = \begin{cases} 0, & para = 0 \\ \frac{1 - HGC}{para} + \frac{SGC + HGC}{2}, & otherwise \end{cases} \quad (3)$$

$$c = \begin{cases} 0, & para = 0 \\ -\frac{((SGC - HGC) \times para - 2(1 - HGC))^2}{8 \times (SGC - HGC) \times para}, & otherwise \end{cases} \quad (4)$$

$$x_{SGC} = \frac{1 - HGC}{SGC - HGC} - \frac{para}{2} \quad (5)$$

$$x_{HGC} = \frac{1 - HGC}{SGC - HGC} + \frac{para}{2} \quad (6)$$

$$exposure = \frac{\mathbf{ShadowGainControl}}{4} + 0.5 \quad (7)$$

$$expgain = v\left(\frac{L_{source}}{L_{target}}, L_{target}\right)$$

where: (8)

L_{source} = Maximum Display Mastering Luminance
L_{target} = **TargetedSystemDisplayMaximumLuminance**

$$SGC = expgain \times exposure \quad (9)$$

$$HGC = \frac{\mathbf{HighlightGainControl}}{4} \quad (10)$$

$$para = \frac{\mathbf{MidToneWidthAdjustmentFactor}}{2} \quad (11)$$

$$a_{Adj} = TMO(a_{SW}) \quad (12)$$

App. 1 — Color Transform in Parametric Tone Mapping (Dolby)

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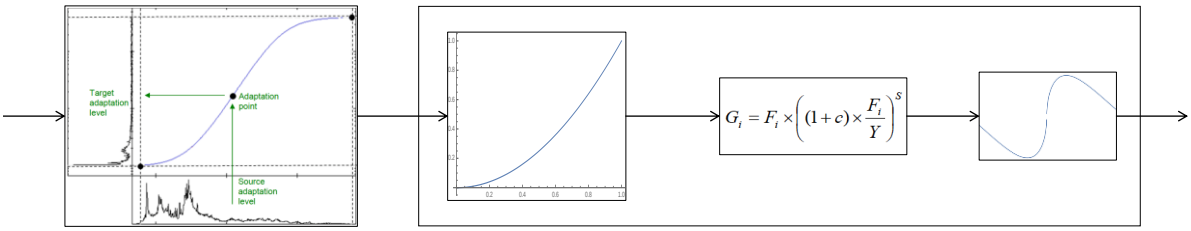
Automatic, data-driven

Optional, under manual control



Data-driven tone mapping
min/avg/max clip RGB

Colorist's
Lift, Gamma, Gain

Boost
Saturation

Enhance
Details

App. 4 — Color Transform in Scene-based Color Volume Mapping (Samsung)

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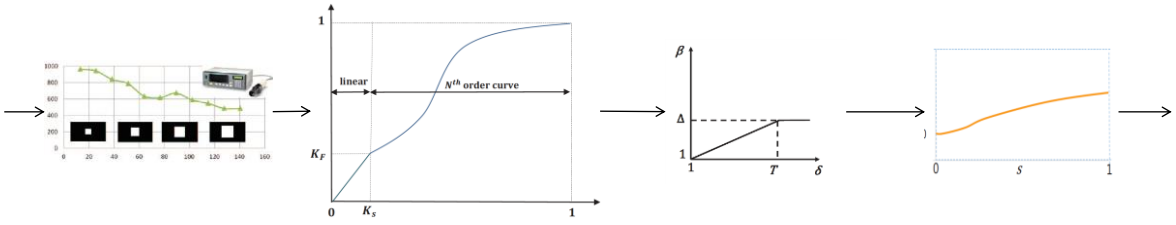

Normalized by
Actual Peak
Luminance

Tone Mapping Curve
In Normalized space

Auto-Gain
Tinted
Clips

Boost
Saturation

App. 3 — Color Transform in Reference-based Color Volume Remapping (Technicolor)

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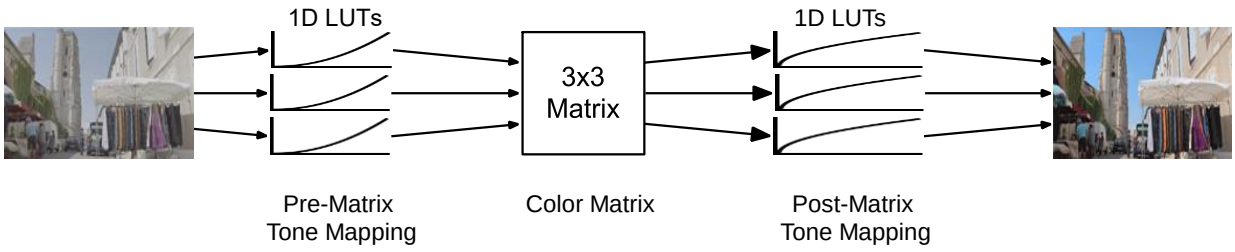
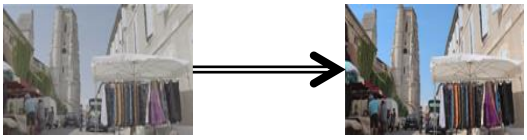


Metadata is not manually created. Calculated through data fitting between two grades of same clips



The DMCVT HDR Flow

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Mastering	Production	Distribution	Viewing
Color grade Non-destructive Manual or auto Save as DMCVT In MXF or sidecar Carry on SDI & IP (coming)	DMCVT in IMF (coming) DMCVT in AVC SEI, HEVC SEI Convert HDR to SDR DMCVT for SDR	HDR media (VOD or Ultra HD Blu-ray) carry DMCVT SDR signal with DMCVT Legacy SDR signal	HDR devices DMCVT (coming) DoVi HDR10 HDR from SDR SDR display

Summary

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- Dynamic Metadata for Color Volume Transforms (DMCVT)
  - Can preserve the creative intent in HDR media across a variety of displays
  - Carried in files, video streams, packaged media
  - Standardized in SMPTE ST 2094

New Acronyms, Terms, Standards

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- WCG – Wide Color Gamut - Rec.2020 has 2x more colors than Rec.709
- HDR – High Dynamic Range TV (ITU-R BT.2100)
- SDR – Standard Dynamic Range TV (Rec.601, Rec.709, Rec.2020)
- HFR – High Frame Rate (100 & 120 fps)
- HEVC – High-Efficiency Video Codec (ITU-T H.265) - 2x more efficient than AVC
- PQ – Perceptual Quantizer Transfer Function for HDR signals (SMPTE ST 2084, ITU-R BT.2100)
- HLG – Hybrid Log Gamma Transfer Function for HDR signals (ITU-R BT.2100)
- HDR10 – 10-bit HDR using BT.2020, PQ and static metadata
- Mastering Display Metadata – SMPTE ST 2086 (min/max luminance, color volume)
- MaxCLL – Maximum Content Light Level
- MaxFALL – Maximum Frame-Average Light Level
- DoVi (Dolby Vision) – 12-bit HDR, BT.2020, PQ, Dolby Vision dynamic metadata
- DMCVT - Dynamic Metadata for Color Volume Transforms, SMPTE ST 2094
- Ultra HD Blu-ray – HDR disc format using HEVC, HDR10, and optionally Dolby Vision
- UHD Alliance Premium Logo – High-end HDR TV requirements

Q&A – Verbal Questions Encouraged!

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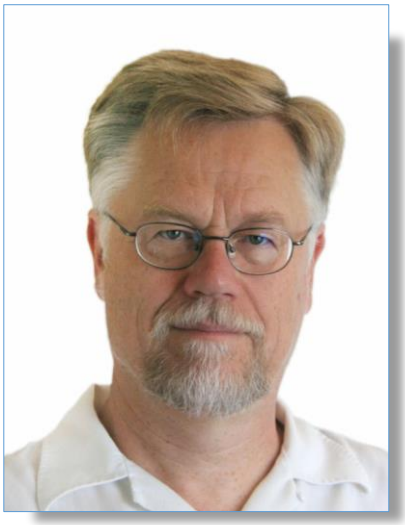

Joel E. Welch