# NEW IMMERSIVE AND OBJECT-BASED MULTI-CHANNEL AUDIO FORMATS FOR CINEMA, ENTERTAINMENT AND CINEMATIC VR

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Xperi Corp. / DTS

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IEEE Signal Processing Society

# IN THIS HOUR. . .

Commercial entertainment experiences can now include high-resolution video presentation covering the full visual field (angular + depth).

Recent developments in cinema and Blu-Ray: audio *with height.*

What are suitable formats and workflows for immersive audio?

… and what about audio-only immersive experiences?

A turning point – immersive *media*

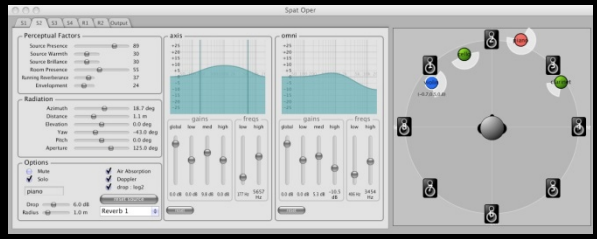
Audio and video scenes no longer spatially “disjoint”, but *“congruent”*

*Movies, live performance, user-generated content, VR...*

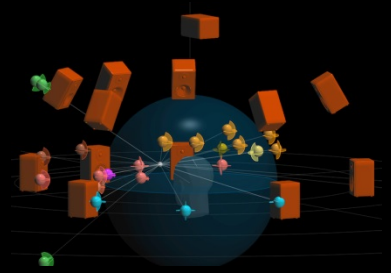
*... a new era in media experience expectation.*

# IN THIS HOUR. . .

- Early developments
  - Immersive audio creation, encoding and rendering
  - Approaches to format-agnostic audio



- New formats for *immersive linear audio*
  - Creation, workflow, cinema
  - Distribution, broadcast, streaming



- Cinematic VR
  - Binaural 3D audio and Ambisonic techniques – *the return!*

- Pending issues, perspectives
- Q&A

# IMMERSIVE AUDIO

*Non-linear* – *interactive | computer generated*

Video games | simulation | interactive VR

Live performance: music | multimedia | dance | theater | DJ

Also… creation (mixing) of *linear* content…

*Linear* – *scripted | recorded*

Recording: music | radio drama | movie soundtrack | cinematic VR

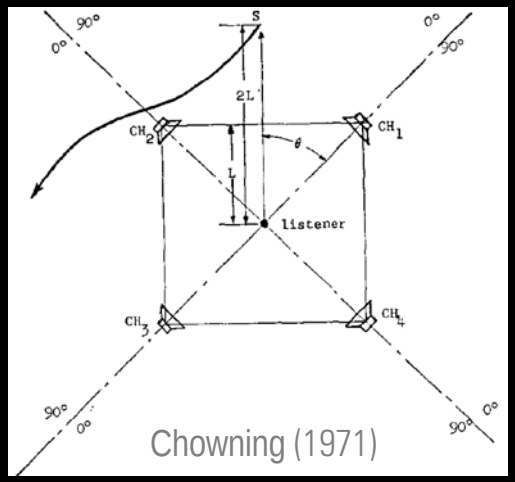
Content creation: computer-assisted mixing + automation

Also… live recording of *non-linear* content production or performance

# NON-LINEAR OBJECT-BASED IMMERSIVE AUDIO

Workflow based on game authoring/rendering technology (late 90's – now)

Origins: computer music, concert hall acoustics research (since 70's)



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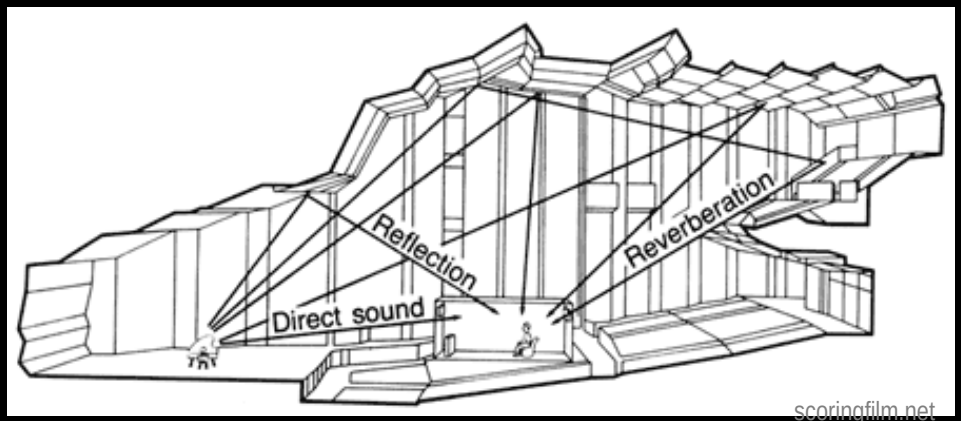

scoringfilm.net

Recent progress accelerated by rebirth of VR technology

supported by progress in computing hardware performance.


businessinsider.com

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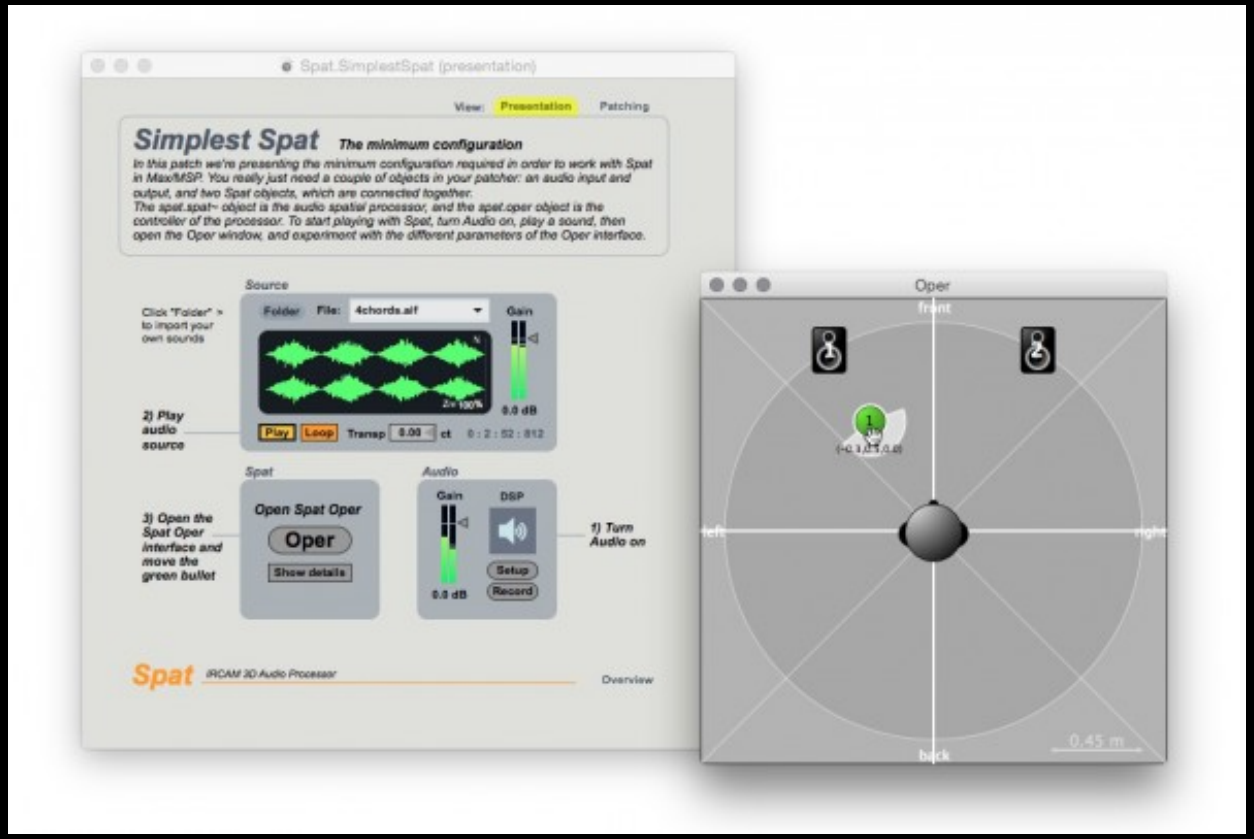
# Beginnings...

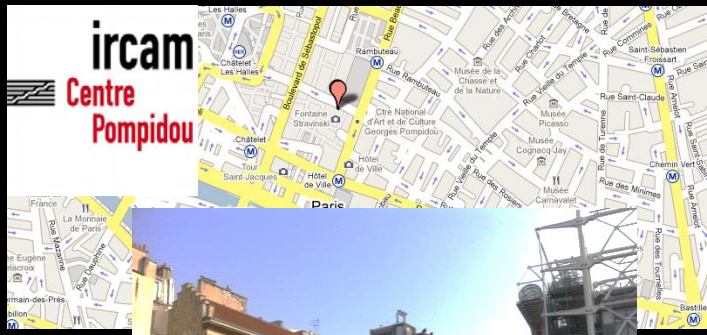
Telecom Paris
1989-1992

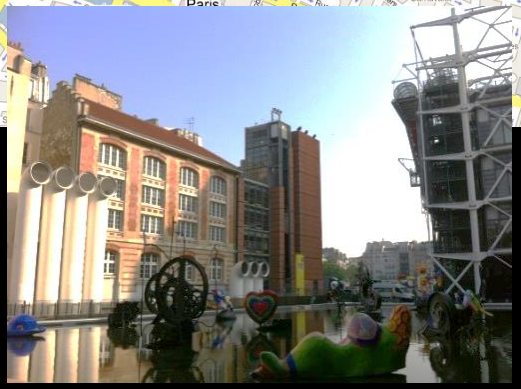
FDN (Feedback Delay Network) artificial reverberation.

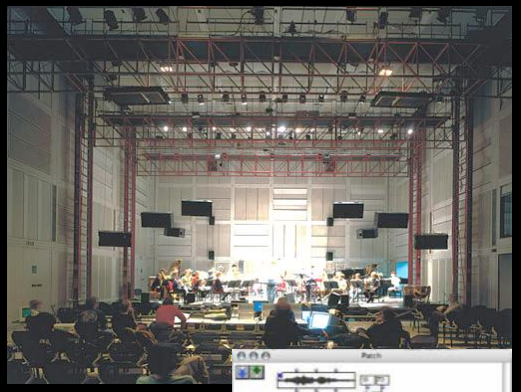
IRCAM
1993-1998

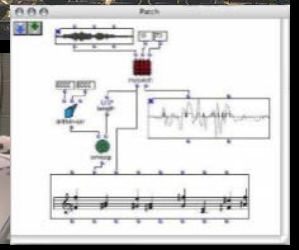
*Spat* – room acoustics and spatial audio for computer music.



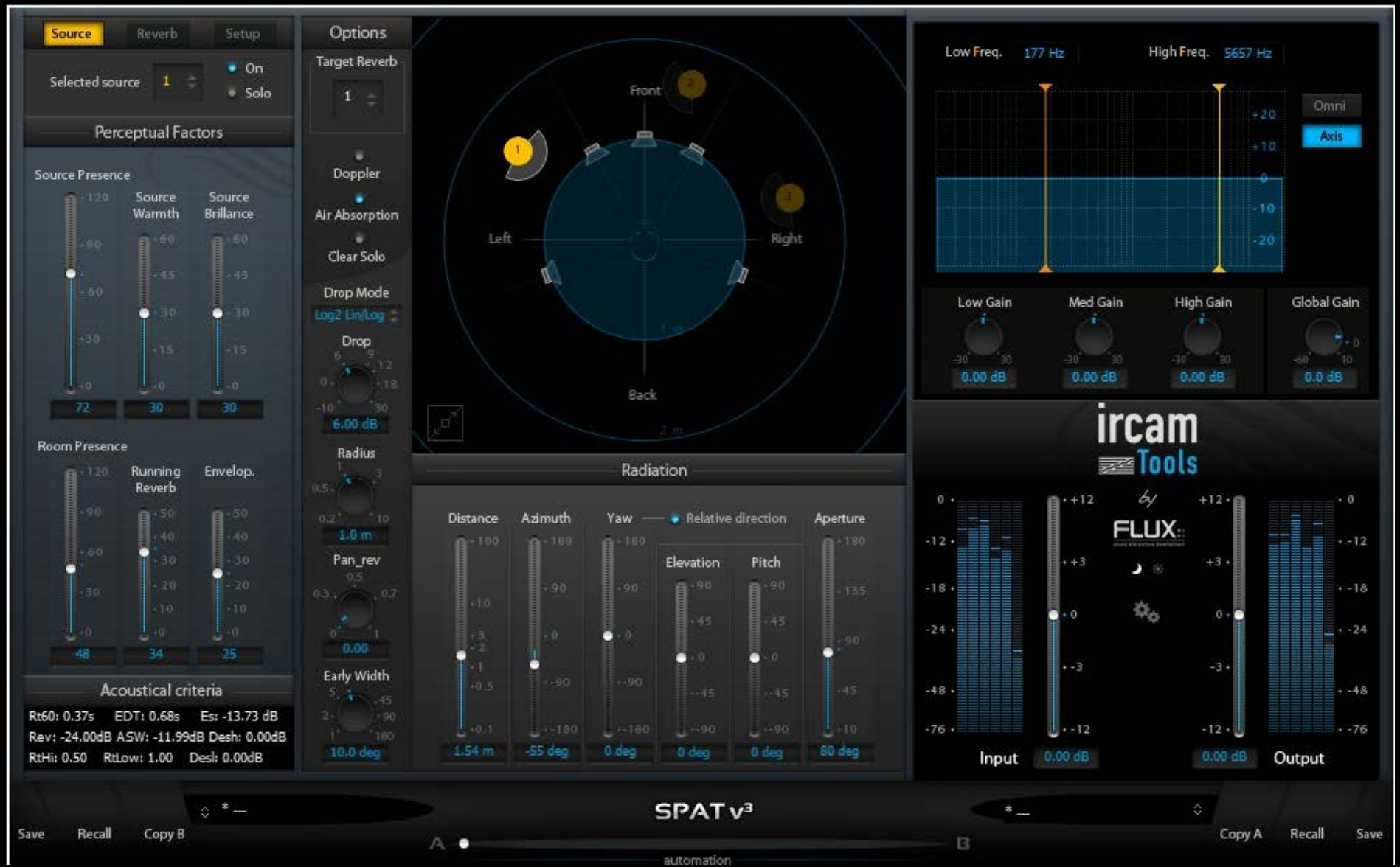







# FLUX:: IRCAM Spat (2010)

www.fluxhome.com/products/plug_ins/ircam_spat-v3 | forumnet.ircam.fr/product/spat/

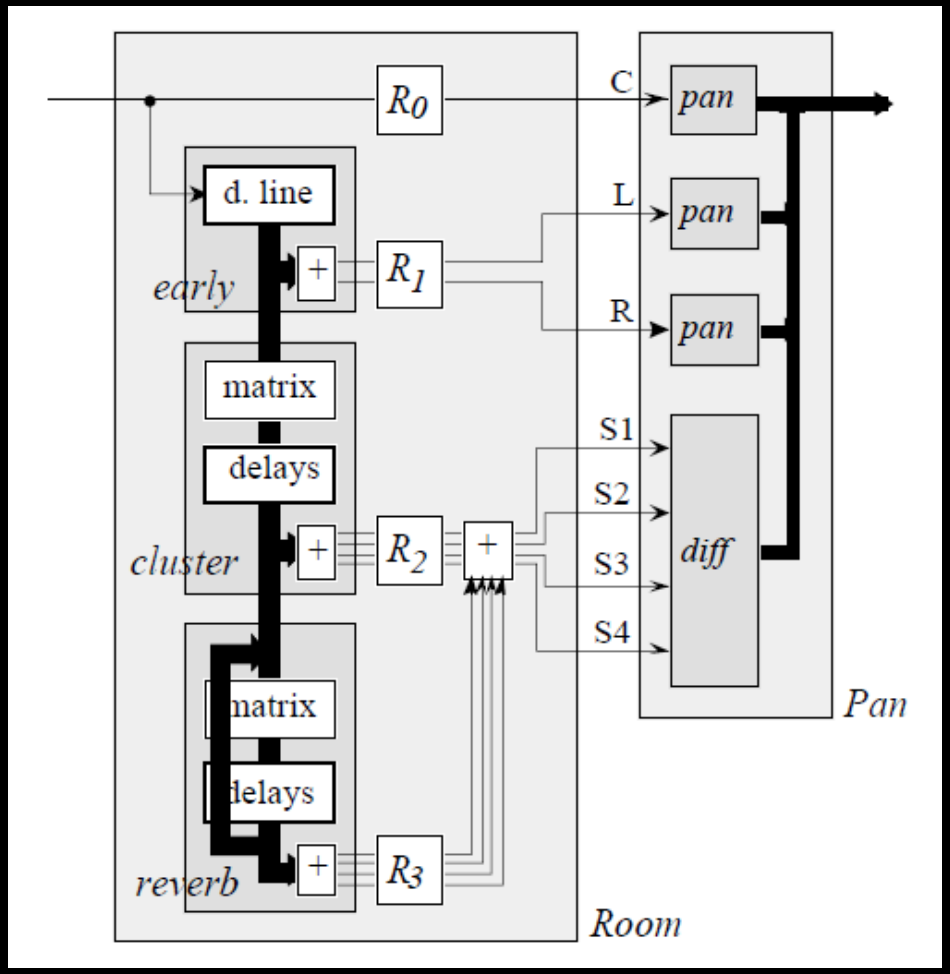


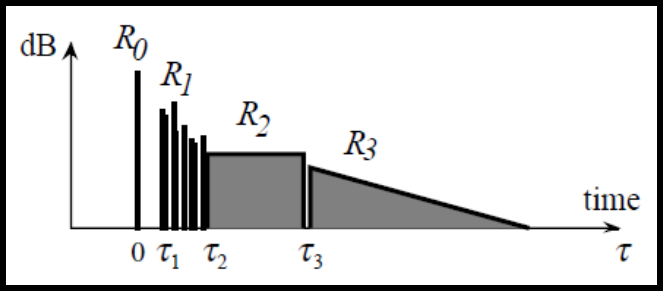
# FLUX:: IRCAM Spat v3 – demo

www.youtube.com/watch?v=XPLSrY4xLRw

... controlling reverberation & source parameters: Distance / proximity, Yaw (orientation), Aperture (directivity)

# Spat – generic per-source processing architecture




Directional early reflections

Diffuse reverberation

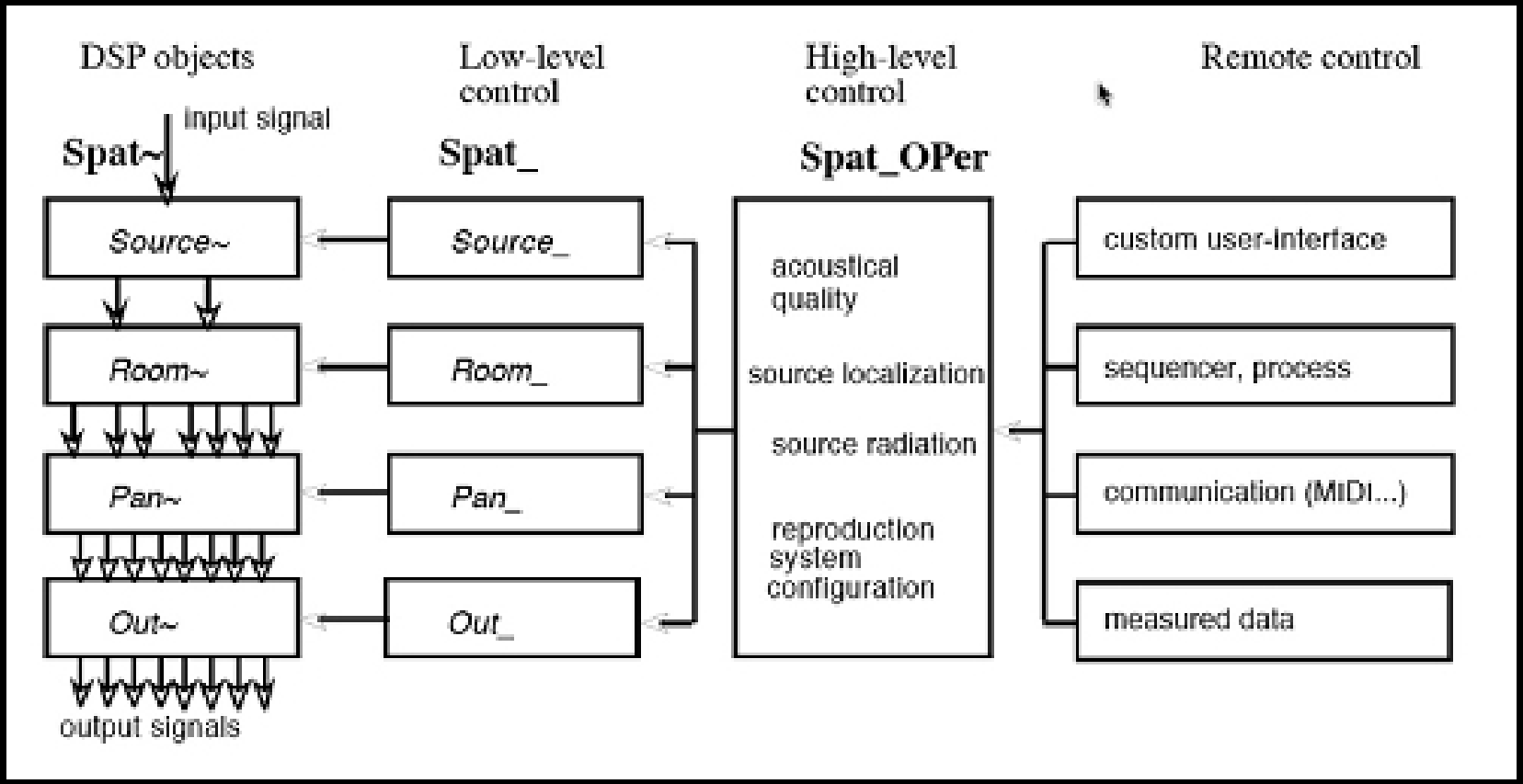
Per-source perceptual controls

Format agnostic representation

Library of “Pan” modules

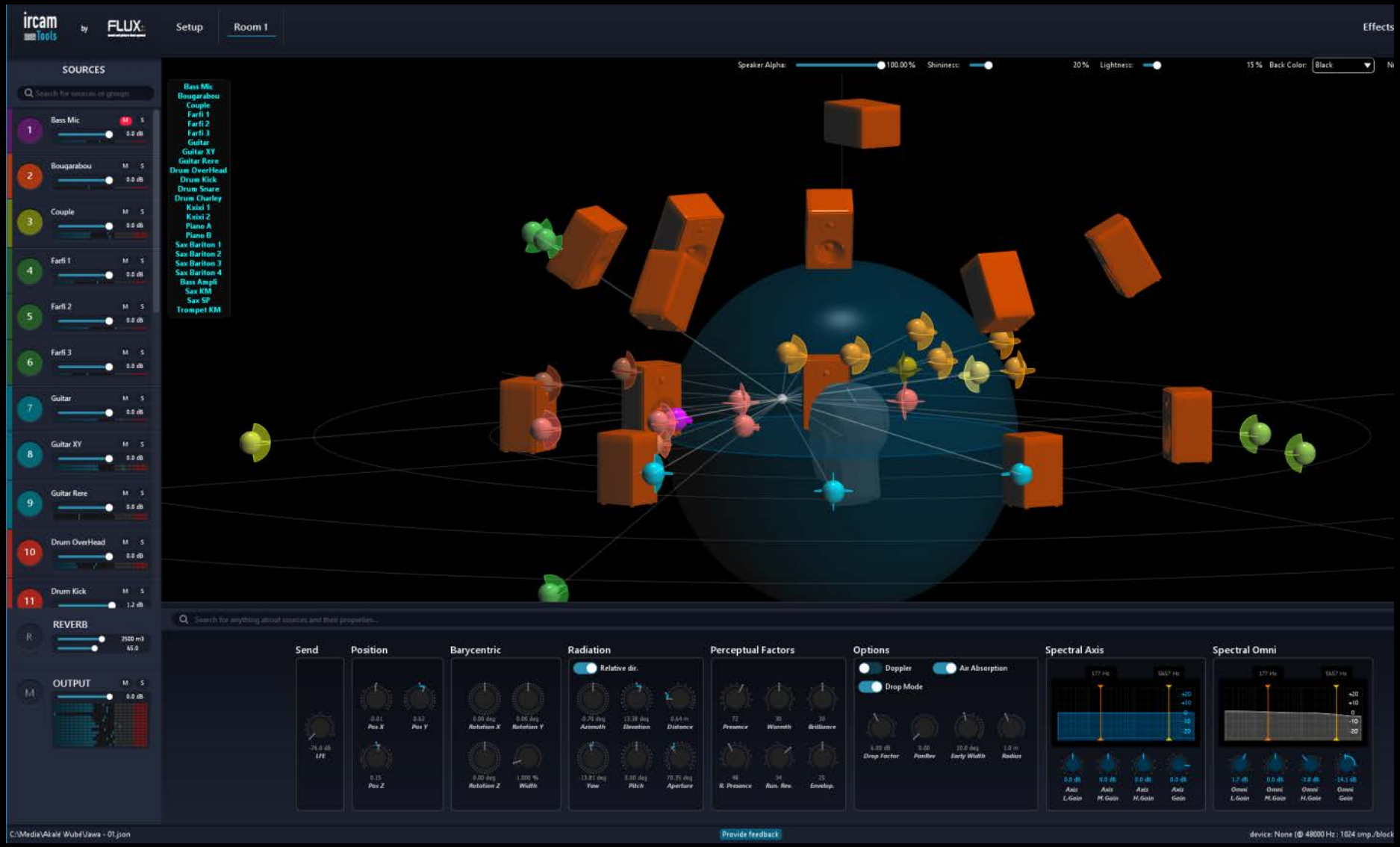
Extensible: immersion with height.

# Spat – generic per-source processing architecture



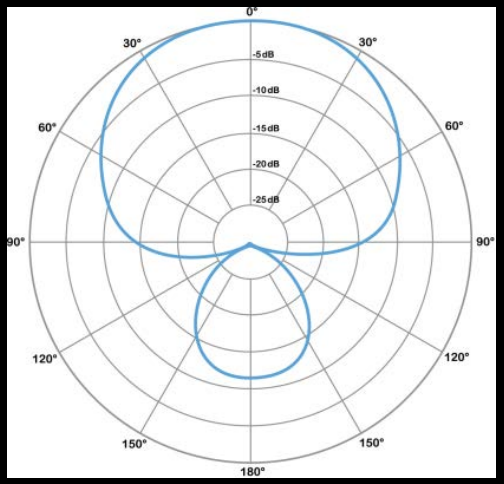
# FLUX:: IRCAM Spat Revolution (2017)

http://www.spatrevolution.com/



# DIRECTIONAL AUDIO ENCODING AND RENDERING

Designing the elementary "*pan*" module




## Recording vs. "panning"

- Common framework: pan law ⇔ microphone directivity
- Criteria. Re-recording principle. Psychoacoustics.

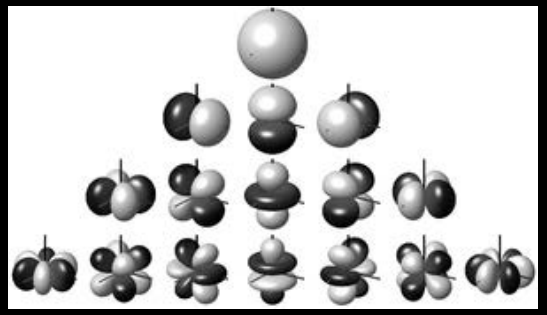
## Binaural reproduction – microphones = ears

- Dummy head. BRIR, HRTF measurements. Head-tracking. Cross-talk cancellation.
- Performance limitations, challenges (more later re. VR audio). Cognitive factors!

## Ambisonics – microphones = spherical harmonics (or linear combinations thereof)

- First-order Ambisonics (FOA) – 4 channels
  - LF and HF decoder solutions
  - Gerzon localization vectors
  - Global interpolation over all speakers.

- High-order Ambisonics (HOA) – more channels: 9, 16...
  - Linearly extend sweet spot size vs. order/frequency ratio.



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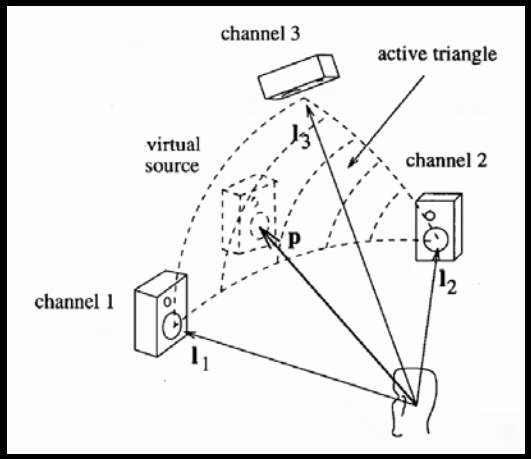
# DIRECTIONAL AUDIO ENCODING AND RENDERING

Designing the elementary "*pan*" module

Amplitude panning – optimizing localization "discreteness"

- *Local* interpolation: panning weights given by centroid of nearest speaker localization vectors.
- Egocentric: e.g. "vector based" (VBAP, VBIP)
- Allocentric: e.g. "distance based" (DBAP)




Holography – pressure field reconstruction over extended area

- Wave-field synthesis (WFS), delay-based panning
- Direction vs. localization, audio vs. visual
- Theoretical equivalence with HOA for increasing order.

Challenges (for "surround" or "immersive" audio)...

- No "one-size-fits-all" solution for consistent experience in all listening conditions
  - => select the most effective rendering technique for given conditions
- Rendering near-field or spatially extended sounds (incl. reverb)
- Listening system calibration, device or room effect compensation.

# Off to the US. . .

Creative Ltd. 1998-2008

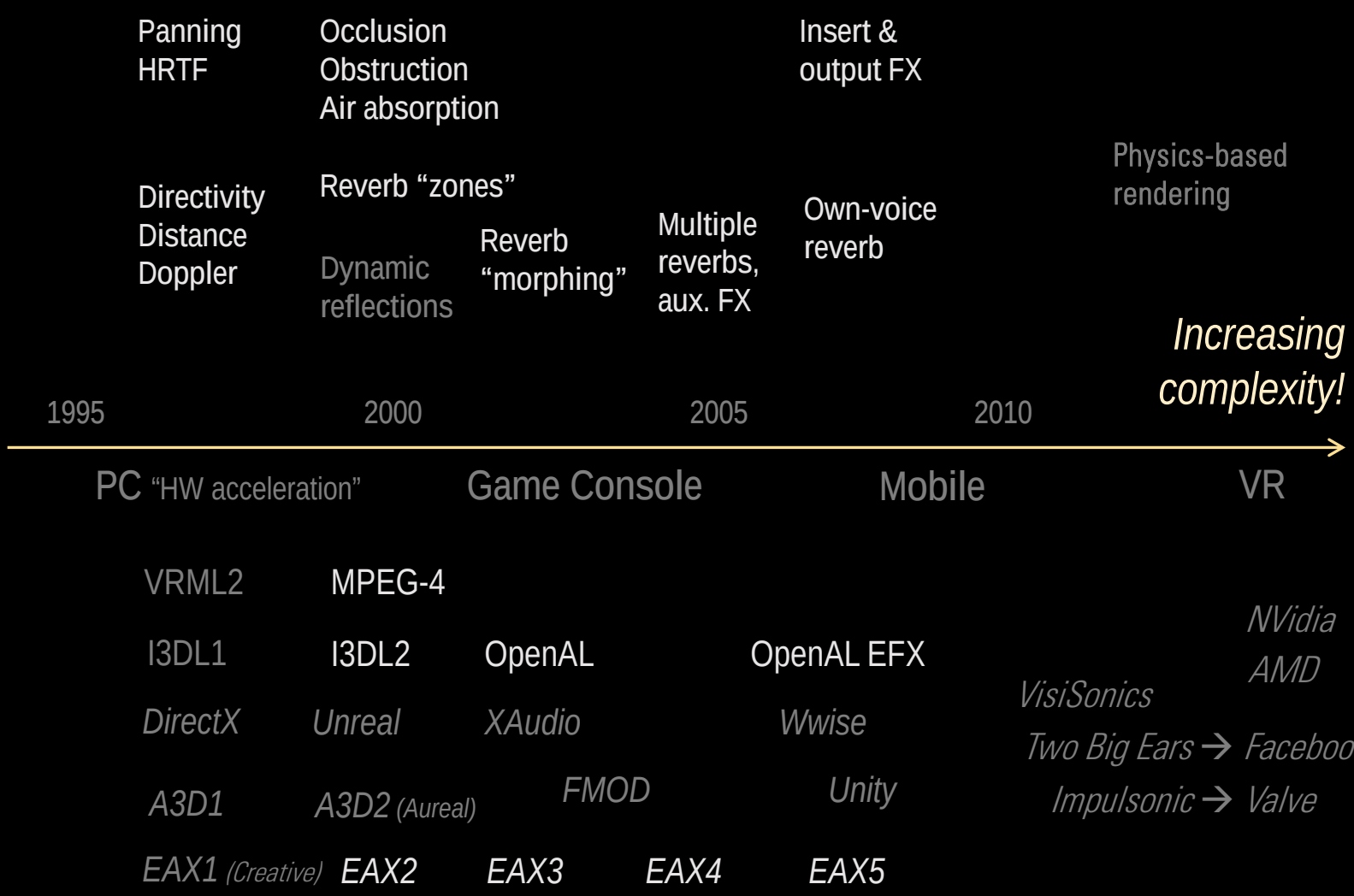
*MPEG-4, EAX, OpenAL* – environmental audio for games. Spatial audio “post-processing”.

DTS Inc.

*DTS:X, Headphone:X* – consumer audio technology. Immersive multi-channel audio




# TWENTY YEARS OF IMMERSIVE AUDIO PROCESSING FOR GAMES / VR



# APPROACHES TO FORMAT-AGNOSTIC AUDIO

- Interactive object-based audio
  - MPEG-4 AABIFS, WFS. EU LISTEN project...
    - IRCAM, Iosono, Sonic Emotion, Astro Spatial Audio...
  - Game audio – EAX, OpenAL EFX (similar to Spat except in room effect control model)
  - Approach ok for non-linear, but not best for ubiquitous linear media content
- Frequency-domain format conversion, parametric approaches
  - Examples: DirAC (Directional Audio Coding), SASC (Spatial Audio Scene Coding)
  - General approach: direct-diffuse decomposition, localization vectors
  - Why frequency domain: sparsity of representation, analogy with human hearing model
- Metadata-assisted unmixing / informed source separation
  - MPEG SAOC (Spatial Audio Object Coding)
  - Informed Source Separation.

# LINEAR IMMERSIVE AUDIO

Real-time rendering implies trade-off on fidelity.

Linear content production allows offline rendering => more MIPS per frame

… for both image and sound (e.g. computer generated animation or video).

For linear immersive audio content archiving and presentation, we need…

*Multi-channel recording format that faithfully encodes spatial audio cues*

*… but agnostic to loudspeaker configuration in the theater;*

*Efficient delivery + faithful rendering in consumer environments*

*… flexible for playback in home, mobile, headphone, automotive scenarios.*

*Create Once, Play Everywhere.*

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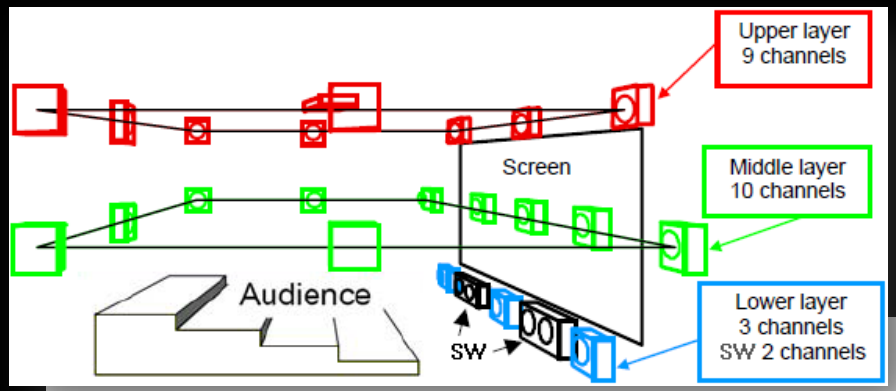
# FROM SURROUND TO IMMERSIVE AUDIO FORMATS

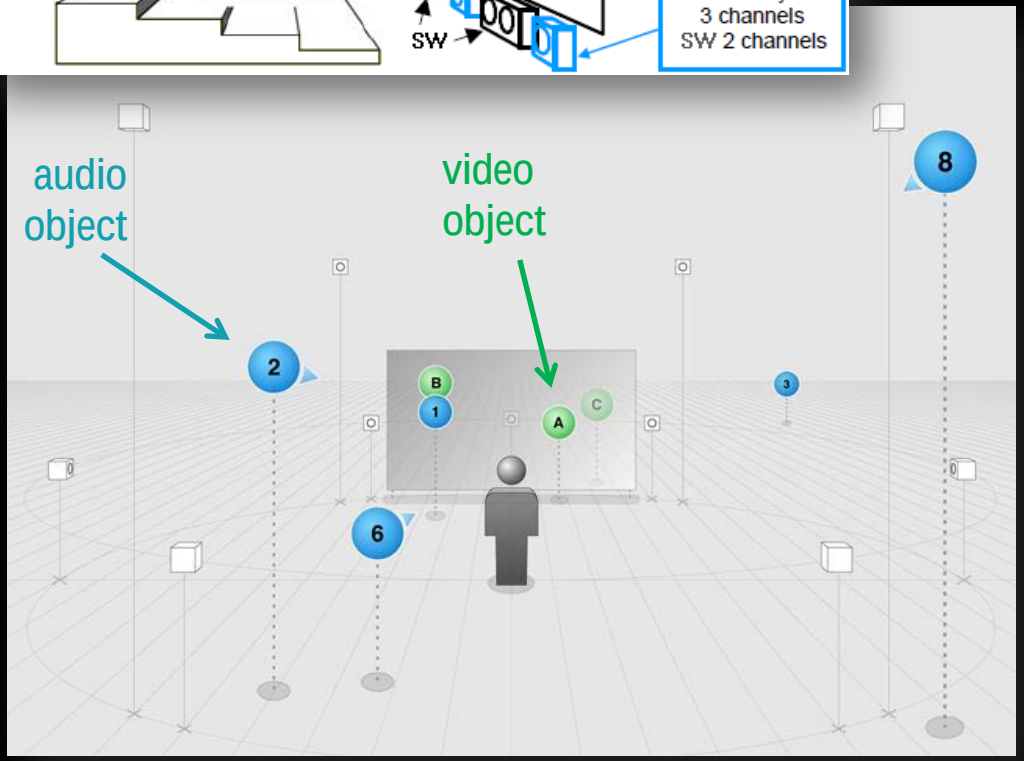
Channel-based / scene-based *fixed* audio formats

- Add discrete “height” channels
- High-order Ambisonics (HOA)
- … *“Baked” audio mix.*




Object-Based Audio – *the return!*

- Audio essence tracks “rendered” into mix at playback time
- Scene description metadata agnostic to playback configuration
- Compromise-free object rendering
- Audio/video spatial congruence.

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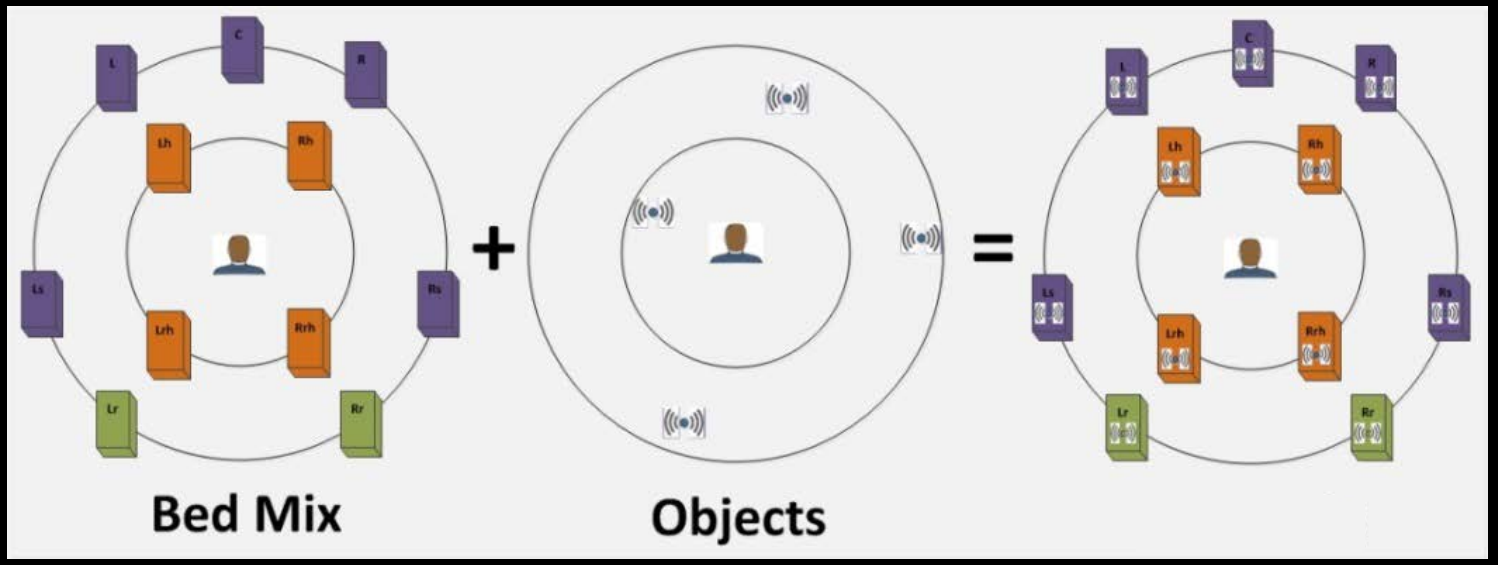
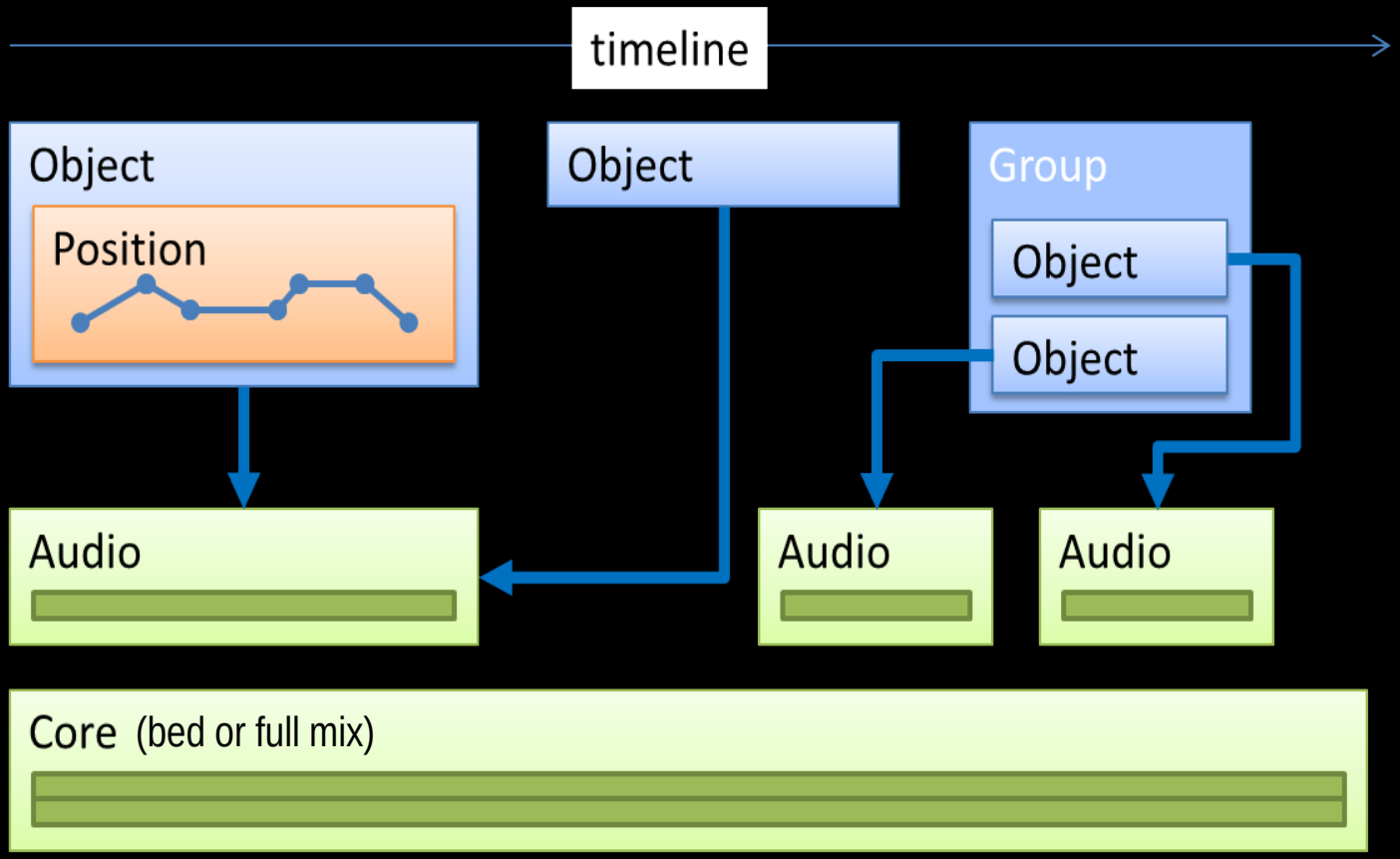
# OBJECT-BASED SCENE DESCRIPTION

Production / theatrical: Auro, Atmos, MDA



# OBJECT-BASED SCENE DESCRIPTION

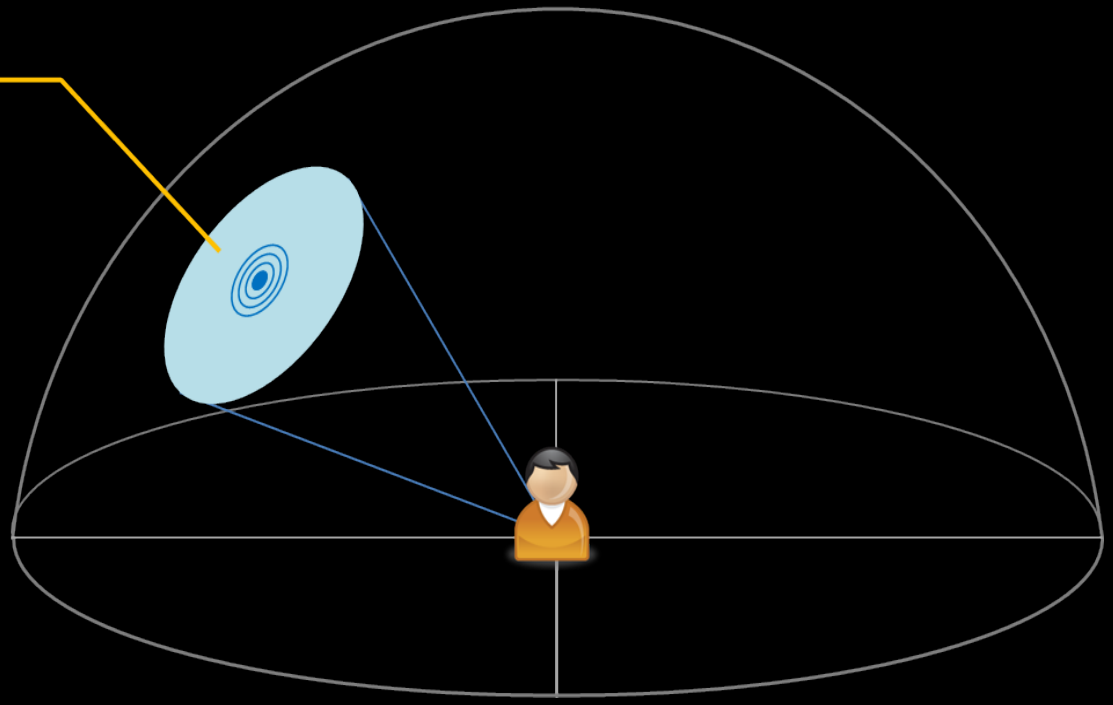
Delivery / disks, downloads, broadcast, streaming: DTS:X/MDA, Dolby AC4/Atmos, MPEG-H/ADM



# AUDIO OBJECT PROPERTIES – “moving virtual loudspeaker”

Note: reverberation is encoded in the bed mix

- Identifier
- Asset Type (e.g. ‘dialog’)
- Gain
- Position
- Spatial extent
- Render exceptions
- Priority
- Loudness control data
- DRC data
- Dialog control data
- …



dts LISTEN

# MDA CREATOR IN PRO TOOLS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# MDA TOOLS FOR OBJECT-BASED, IMMERSIVE AUDIO CONTENT CREATION

- Suite of software tools for object based, immersive content production
- Easy integration into existing production workflows and professional environments
- Efficient and flexible solution for today's professional content production needs
- Support for a vast variety of immersive speaker layouts
- No dedicated rendering hardware required
- Full DTS:X ecosystem feature support (Object preservation, Interactive Dialog Control)

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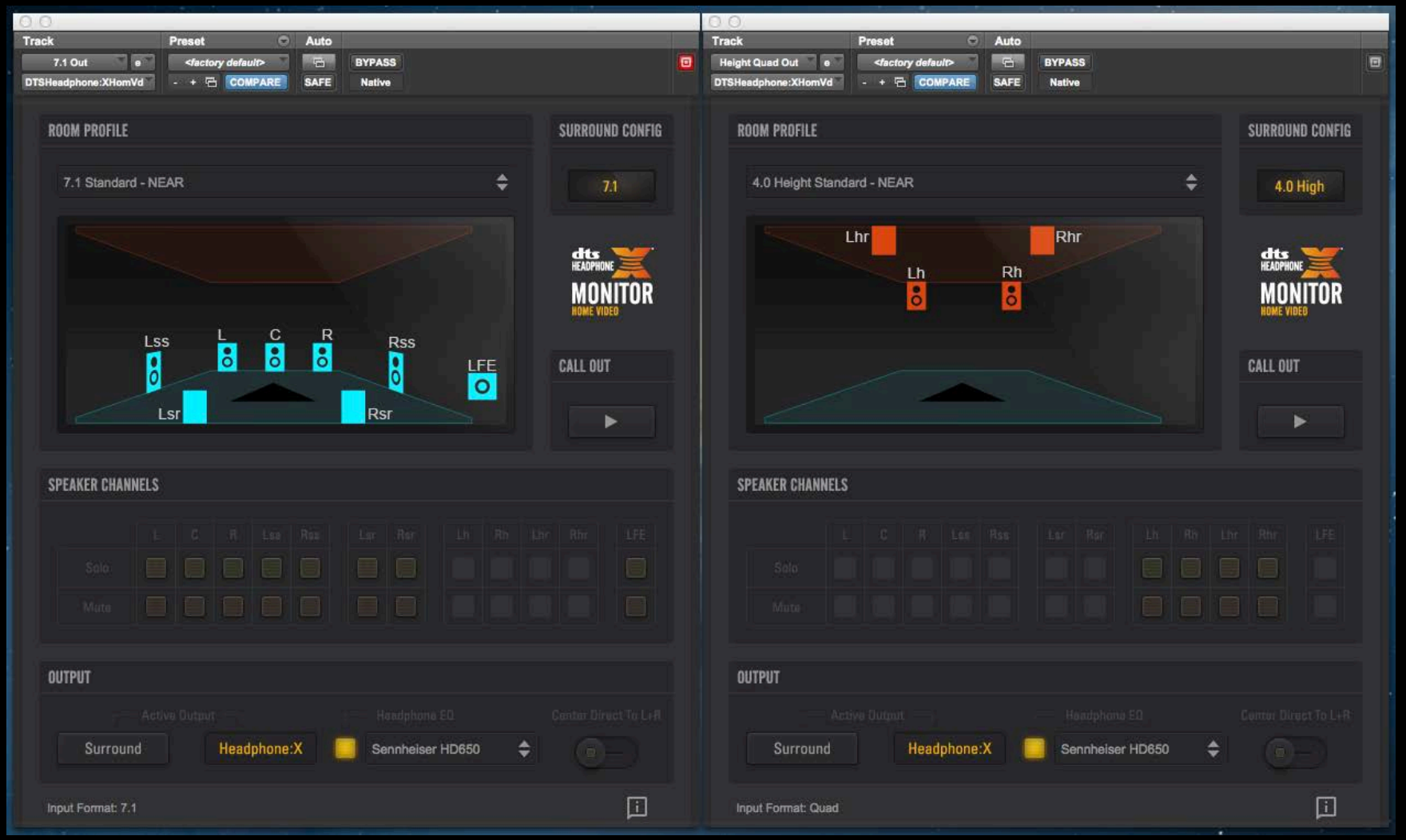
# DTS HEADPHONE:X MONITOR FOR MDA CREATION

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# DTS:X CONTENT CREATION SOLUTIONS

Audio Units Beds

Audio Units Objects

Object-Based Print Master
(Beds + Objects)

MDA bitstream

7.1 PCM + OBAE MXF wrapping DCDM

DCP authoring + QC

Immersive Mix
for Home Video

M2X bitstream for DTS:X Encoding

QC DTS Audio with Video

Author for Blu-ray & UHD Blu-ray and other formats

## MDA Control

- advanced usability for MDA Creator
- Metering

## MDA Creator

- Create immersive mix
- Monitor for different speaker layouts
- Export MDA/M2X
- Create down-stream deliverables

*(Pro Tools plug-in)*

## MDA Stream Tools

- Trim/Scale MDA bitstream
- Reframe MDA to 2000 samples
- Export bed and fragmented OBAE
- MXF wrap OBAE for DCP wrapping

## DTS:X Encoder

- Load WAVs or M2X file
- Select target output & encode settings
- Create object or channel based encodes
- Queue job for encoding

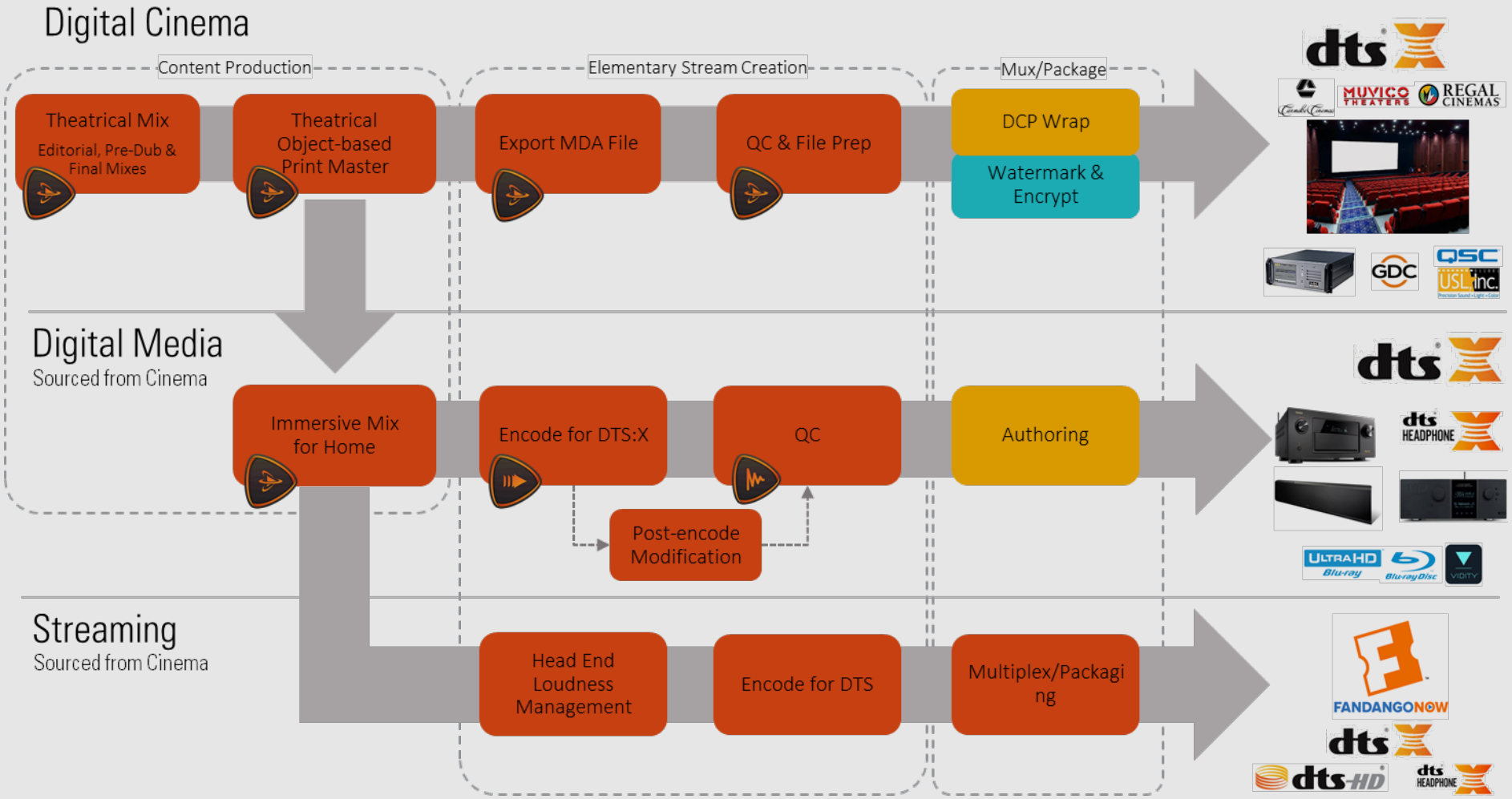
## DTS:X MediaPlayer

- QC audio & video
- Supports DTS audio, AVC & HEVC video
- MP4, MOV, CFF & Elementary file support
- Custom time settings & offset support

## MDA Developer Kit

- MDA SDK
- Rendering, Parsing Packing implementation for 3P developers

# DTS:X CONTENT CREATION SOLUTIONS



# WORLDWIDE ADOPTION – DTS:X & MDA TECHNOLOGY

## Future-proof content mezzanine / archiving format

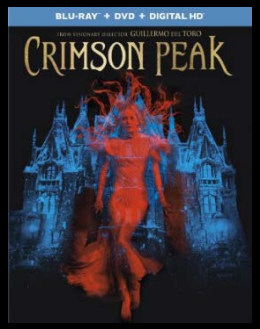
- Published standard specs: ETSI TS 103 223, ...
- Royalty-free in professional content industry

## Worldwide deployment in authoring facilities, theaters and homes (as of Nov 2016)

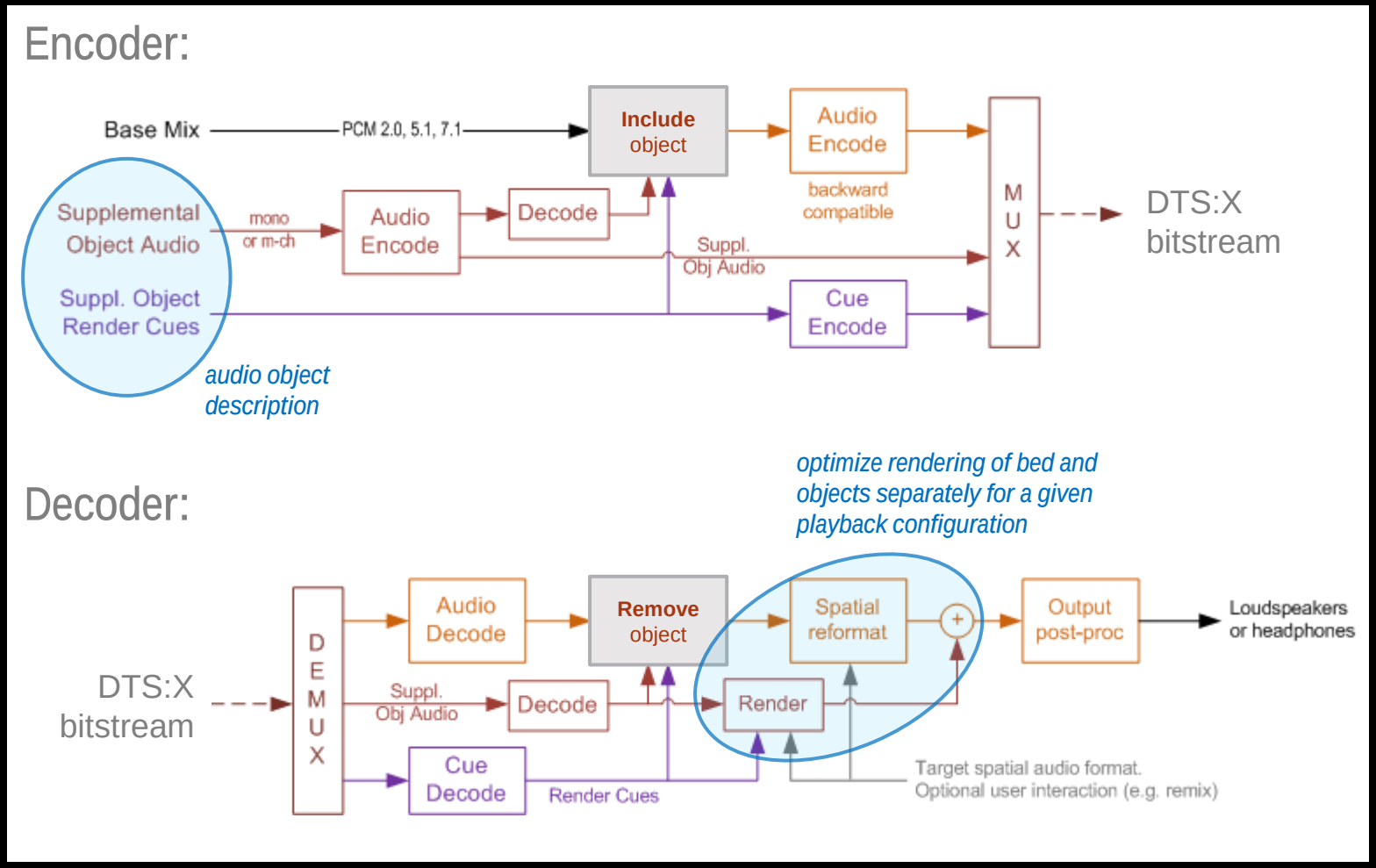
- Over 35 post-production and authoring facilities world-wide
- 130+ DTS:X theatres
- All major AVR manufacturers

GDC Technology Limited

- More than 50 international titles released



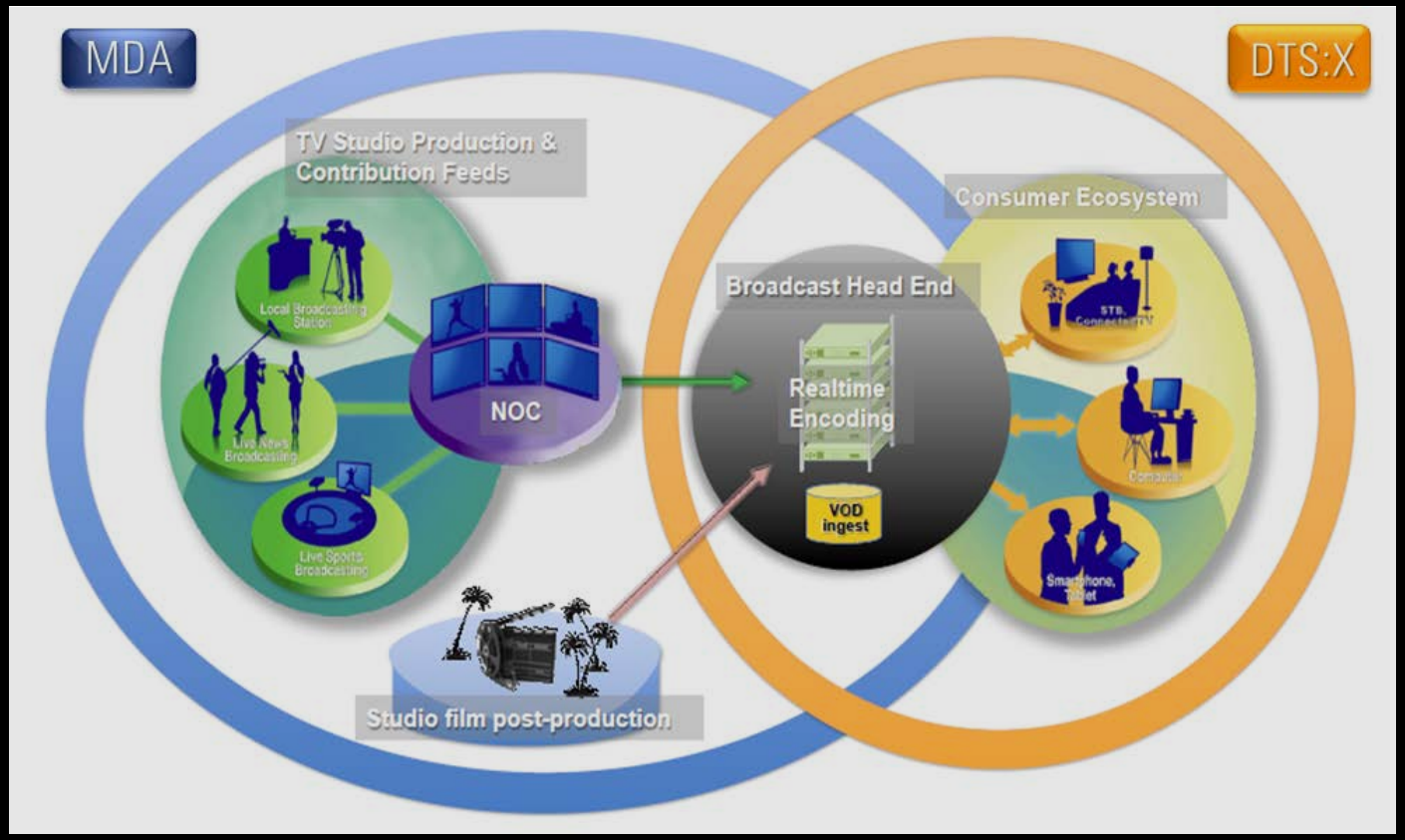
# LEGACY DECODER COMPATIBILITY



# NEXT…

More theaters, homes, film & Blu-ray releases...

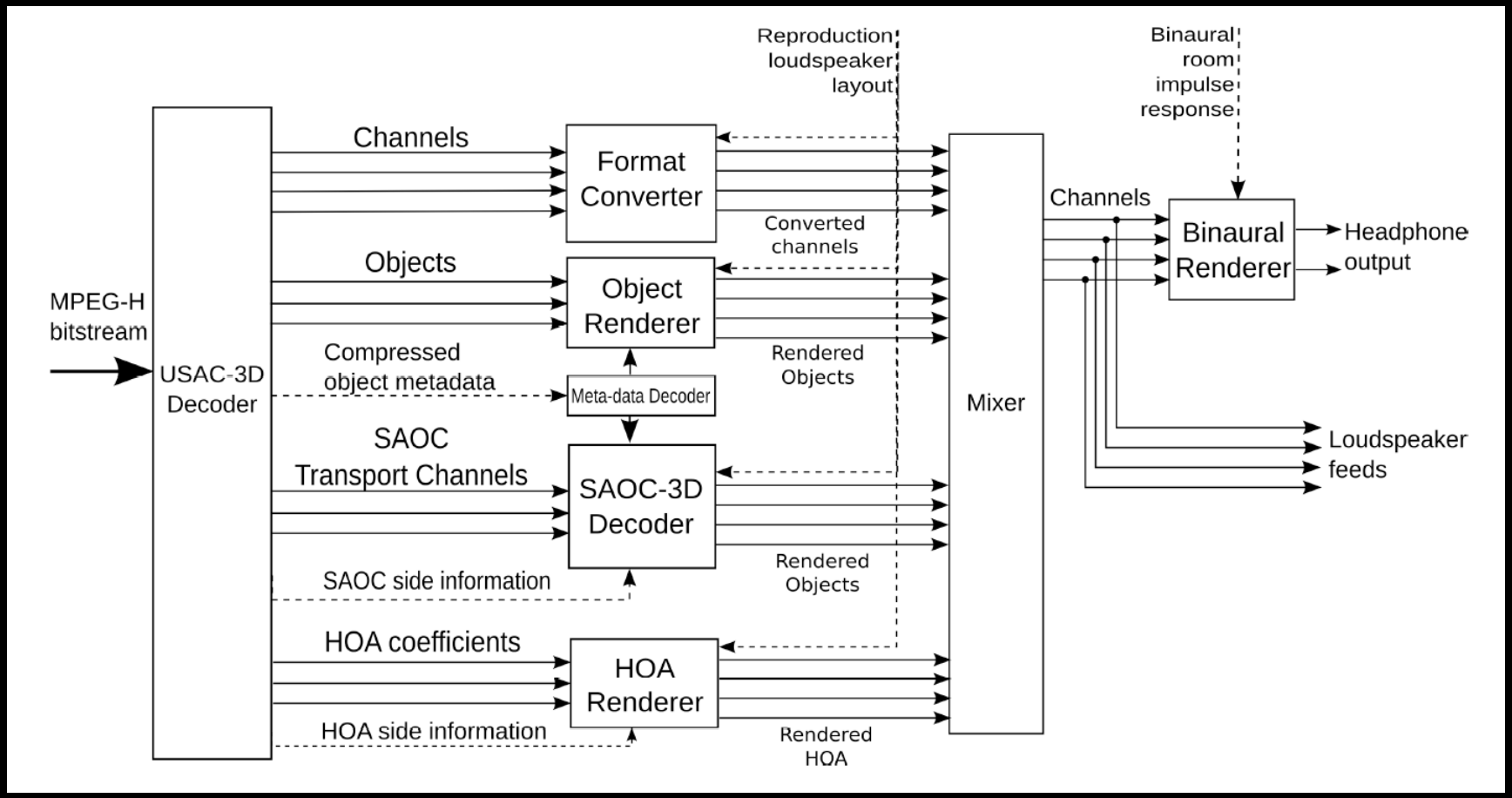
Broadcast, streaming.  Mobile devices.  Virtual reality.



# SCALABILITY FROM LOW BIT RATE TO LOSSLESS

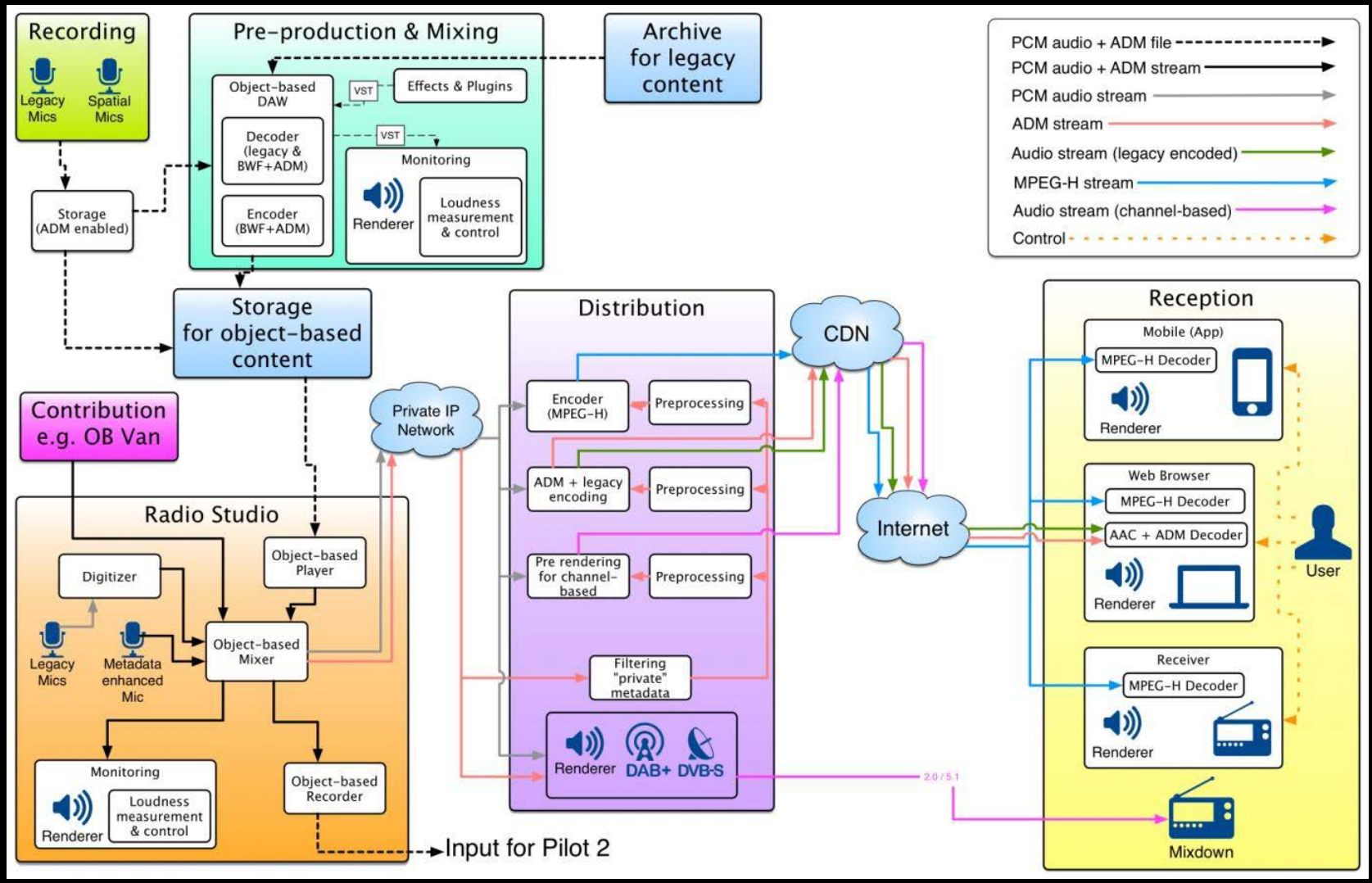
| Channels | Bitrates [kbps] (Operational Range) | Bitrates [kbps] (Nominal range for broadcast quality) |
|---|---|---|
| Mono | 24 - Lossless | 48 - 64 |
| Stereo | 32 - Lossless | 80 - 128 |
| 5.1 | 80 - Lossless | 224 - 300 |
| 7.1 | 128 - Lossless | 256 - 340 |
| 11.1 | 192 - Lossless | 288 - 384 |
| 22.2 | 320 - Lossless | 512 - 640 |

# MPEG-H DECODER



# ORPHEUS – OBJECT-BASED AUDIO EXPERIENCE

https://orpheus-audio.eu/



# CONSUMER EXPERIENCE

… as enabled by object-based audio

## Immersion

- Elevation effects, realistic diffuse sounds/ambiences
- Enable optimal spatial audio fidelity

## Flexibility

- Mobile, Home, Car…
- Non-standard loudspeaker layouts
- Ease of setup

## Personalization

- Dialog intelligibility enhancement
- Dynamics Control
- Ability to “change the mix”
- … to the extent permitted by author

# DTS:X PRACTICAL REPRODUCTION AT HOME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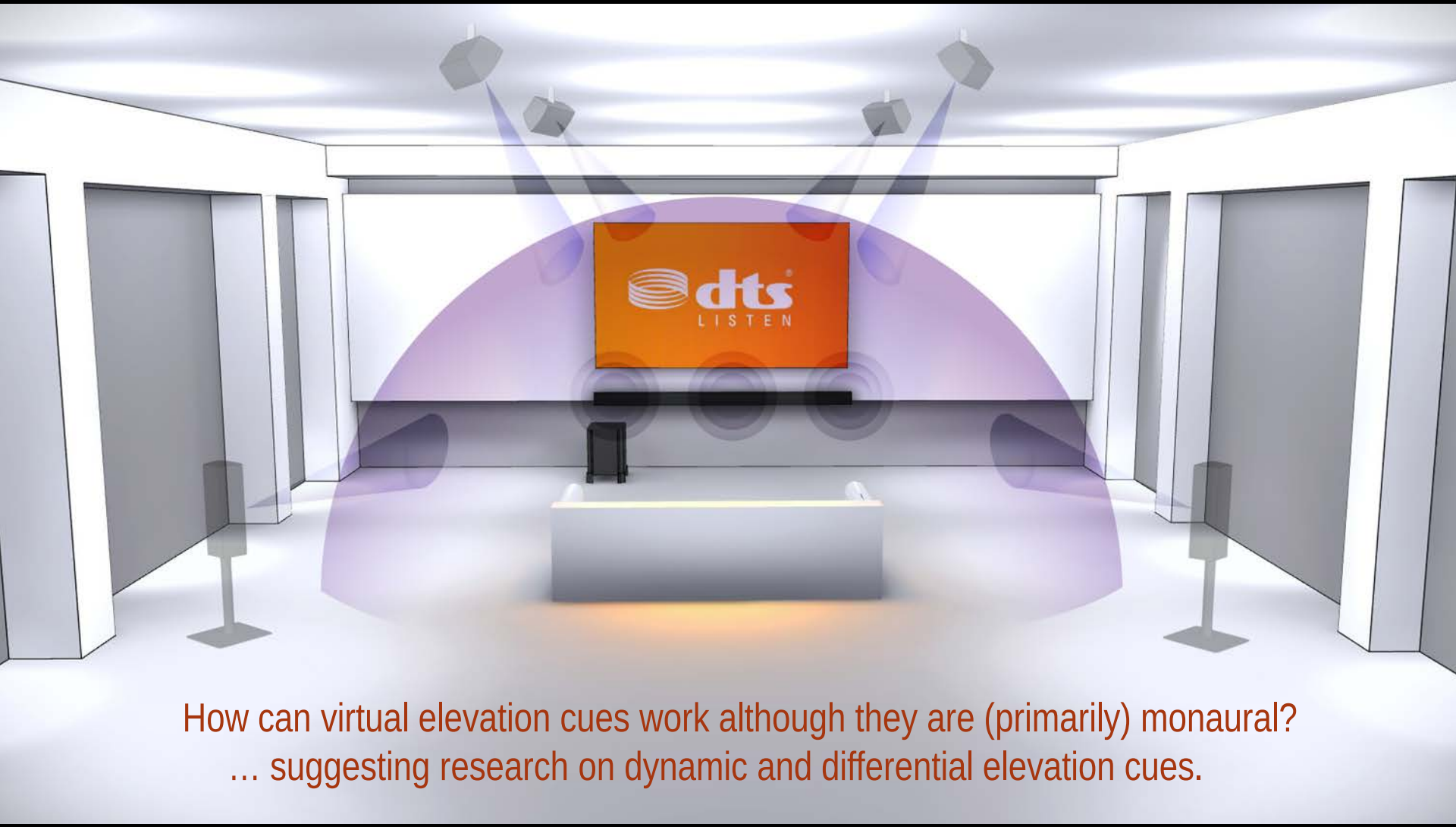
# DTS:X PRACTICAL REPRODUCTION AT HOME

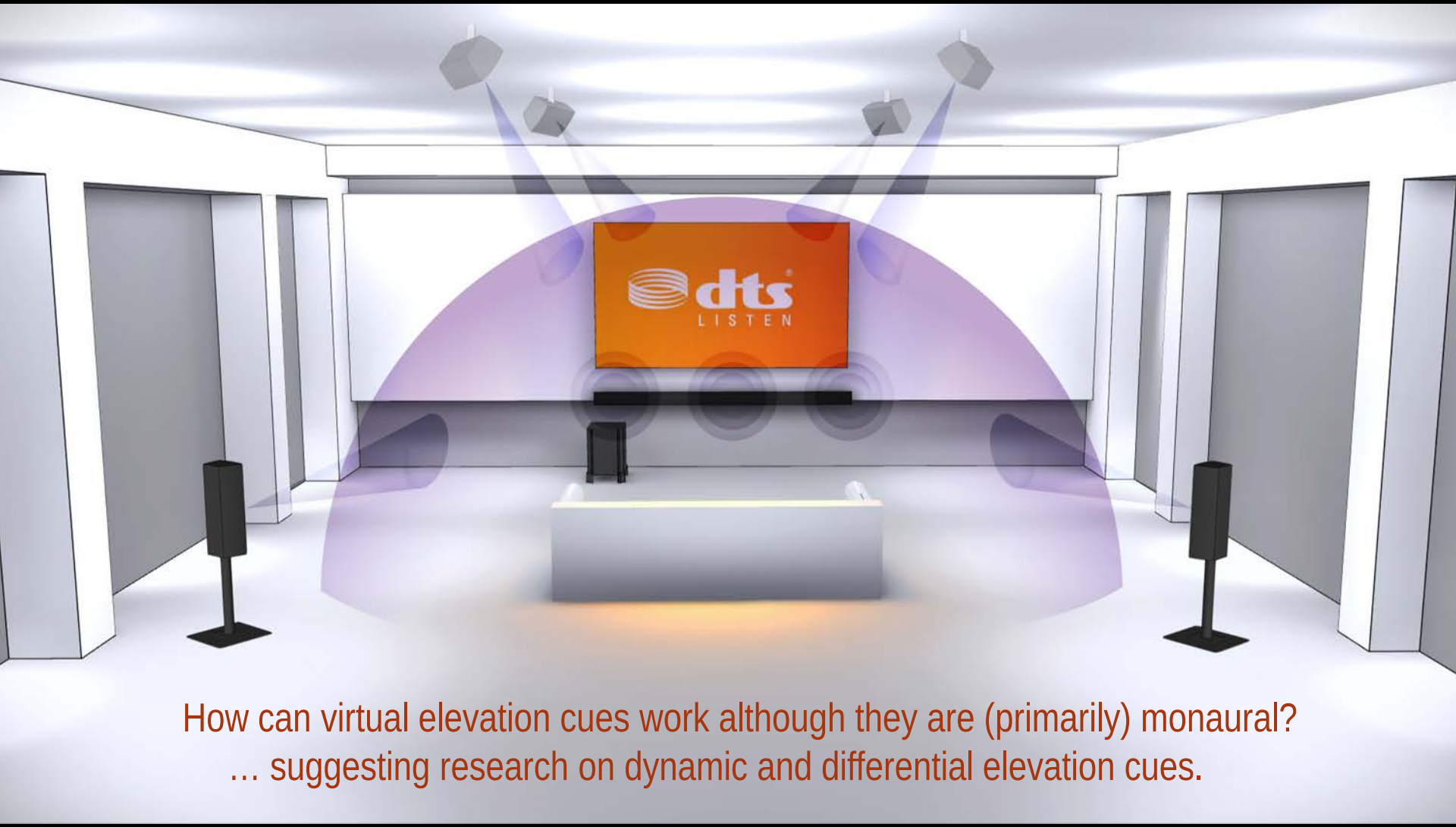
# DTS:X PRACTICAL REPRODUCTION AT HOME

# DTS:X PRACTICAL REPRODUCTION AT HOME – DTS VIRTUAL:X




How can virtual elevation cues work although they are (primarily) monaural?
… suggesting research on dynamic and differential elevation cues.

# DTS:X PRACTICAL REPRODUCTION AT HOME – DTS VIRTUAL:X

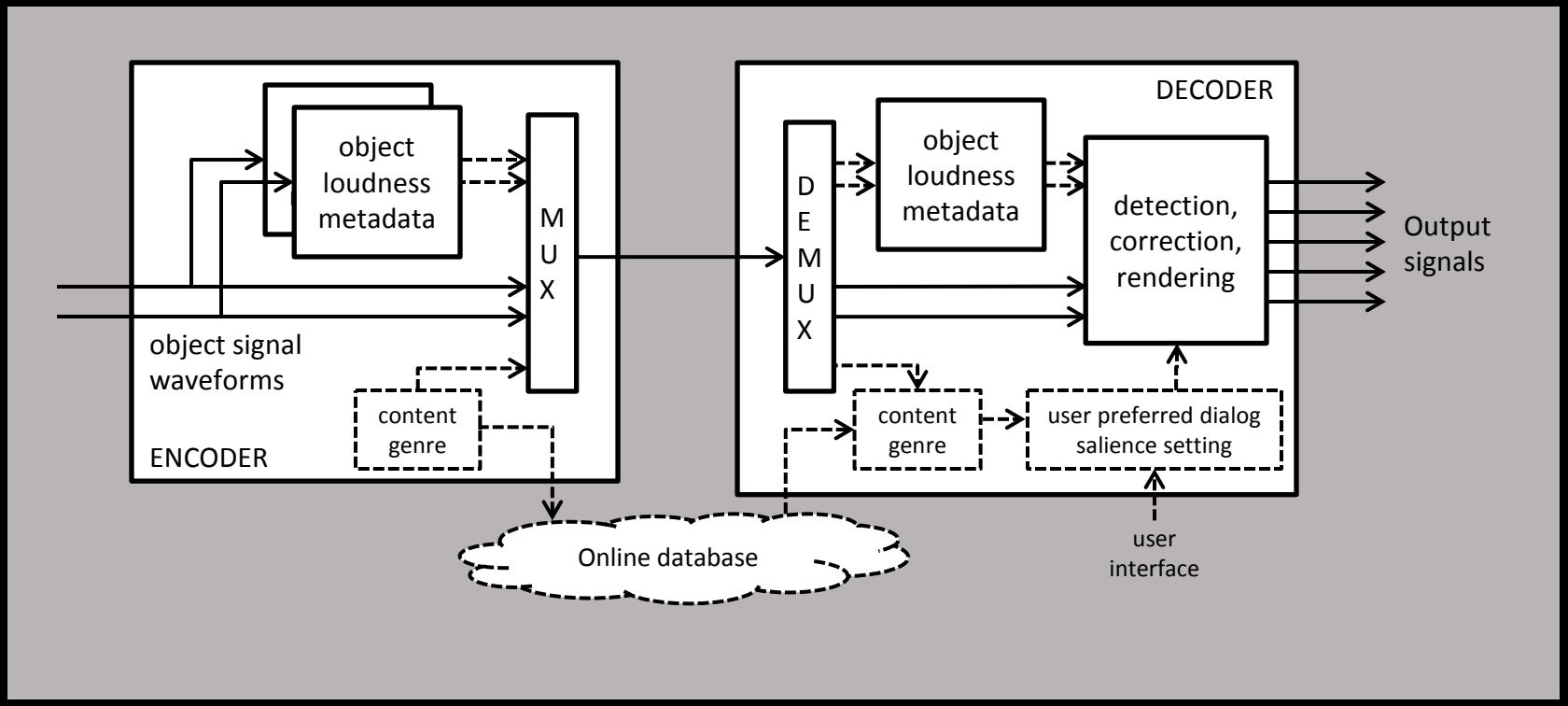



How can virtual elevation cues work although they are (primarily) monaural?
… suggesting research on dynamic and differential elevation cues.

# OBJECT-BASED DIALOG CONTROL

Encode: include loudness metadata

- Global programme loudness, global dialog loudness/salience measures
- Optionally, short-term dialog loudness/salience measure sequence.



# CINEMATIC VR AUDIO — demo

www.youtube.com/watch?v=9RamLHvdfms

Amp Fiddler - "Fiddler on tha Roof" - Output, Brooklyn - 6/24/16 - 360º video with spatial audio

# CINEMATIC VR AUDIO – Ambisonics and HRTF-based virtualization




# CINEMATIC VR AUDIO – Ambisonics and HRTF-based virtualization

## Principles

- Chris Travis 1996 AES paper "Virtual Reality Perspective on Headphone Audio"
- Head-tracking at decode (for *diegetic* sounds)
- Any source format compatible in principle by dynamic speaker virtualization

## Current prevalent internet streaming formats

- Google: Opus low-bit-rate codec + Ambisonics (1st order, 3rd order)
- Facebook

## Perspectives

- Limitation of Ambisonic rendering: frequency vs. order for size of head (ear positions)
- Extension to 6DOF: Ambisonic bed + separate objects...

# MORE PERSPECTIVES ...

Natural-sounding audio scenes accompanying our experience of the environment

- Teleporting into another (virtual) world – "you are there" experience.
- With or without image. Linear or non-linear.
- Success: effortless to tune into virtual scene + tune out real world (by occluding it, for instance)

What next? – Extending our physical world!

- AR (non-diegetic sounds). MR (diegetic sounds).
  - MR in a dark/silent room is equivalent to interactive VR.
- Success: minimize "cognitive effort": listening/visual fatigue, attention conflict
- Examples: telepresence, situational awareness (navigation, alerts...)

# MORE PERSPECTIVES …

Technological implications

- Blurring distinctions between currently disparate media applications/industries
  - Music, movies, games, communication, performance, collaboration, travel…
- Critical role of immersive audio technology: spatial congruence, naturalness
  - Minimize cognitive effort
- Evolve the notion of audio object in immersive audio formats
  - Today: producer/broadcaster engineering perspective
  - Future: neuroscientist/composer perspective
  - Psychoacoustic notion of “sound event,” “audio stream,” “audio emitter”
    - Some previous attempts: IRCAM Spat. EAX, OpenAL…