# 360 video

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# Agenda

Examples from authors projects

Image projections
(Perspective - Fisheye - Cylindrical panorama - Cube maps - Equirectanglar panorama)

Camera summary
(One - Two - More than two)

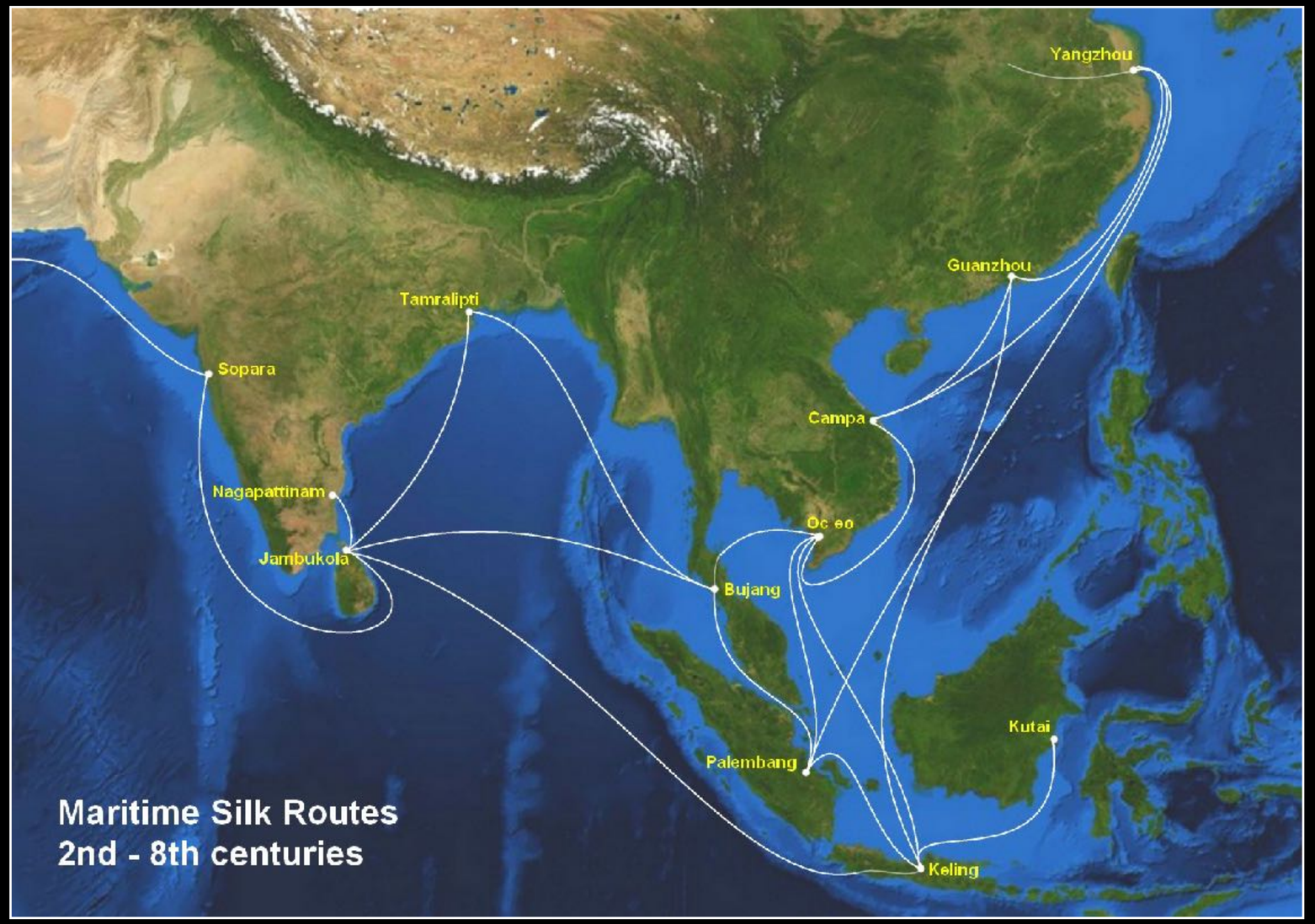
The fundamental problem
(Parallax)

Solutions to the fundamental problem
(Mirrors - Optics - Optical flow)

Miscellaneous topics

Current project

# The Altas of Maritime Buddhism

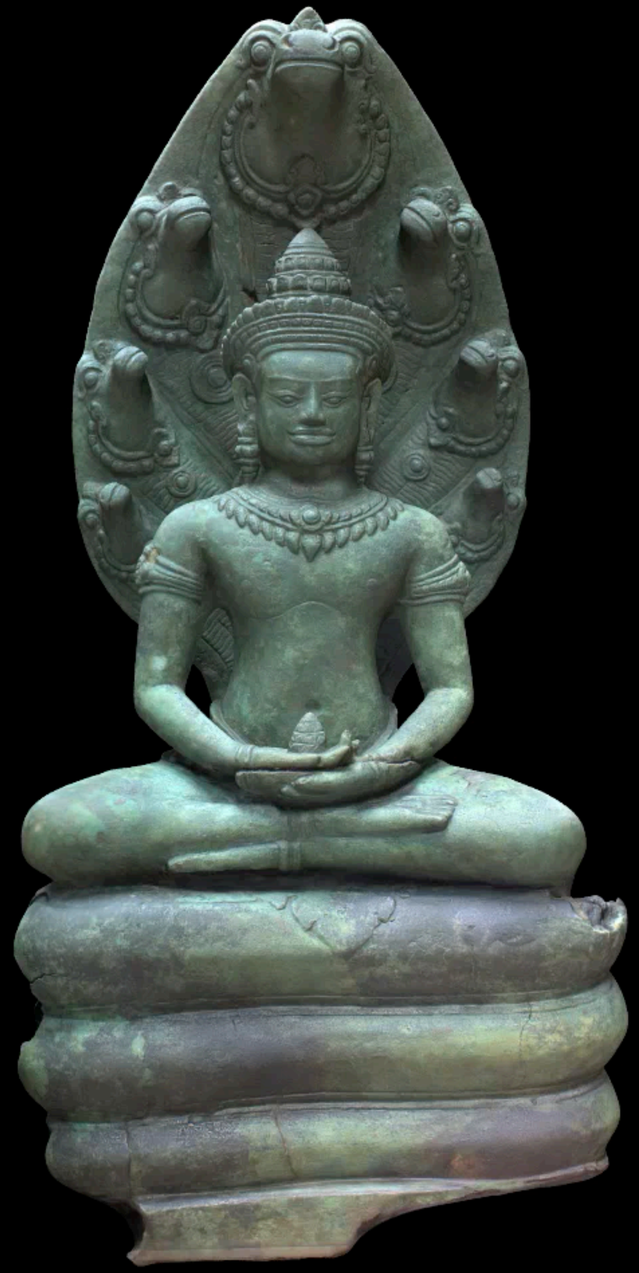


# RoundShot

# Gigapixel

# Gigapixel

# 3D reconstruction



# 360 video

# Repurpose: HMD

# Repurpose: Cylindrical

# Repurpose: Fisheye (domes)

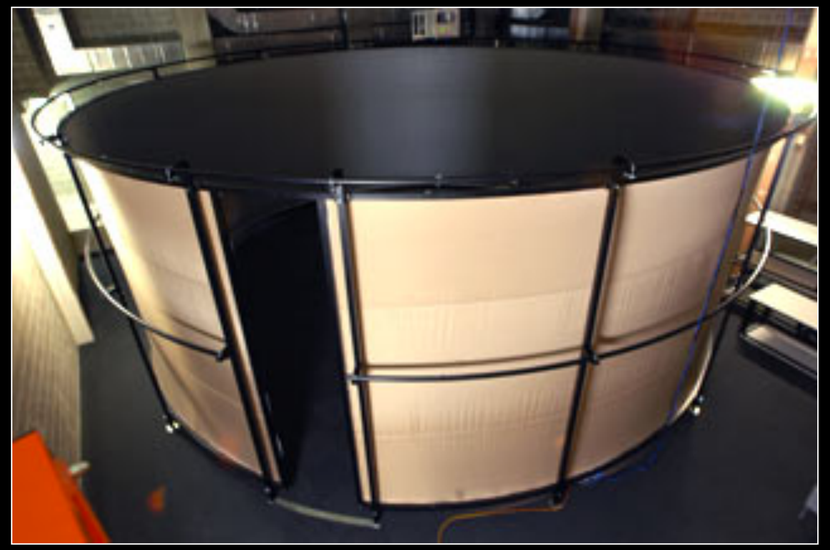
# Repurpose: Perspective

# Insta360Pro2

- 6 Cameras in a horizontal line
- Each camera 190 degrees in order to capture the north pole and lots of overlap for optical flow work (see later).
- 30fps at 8K resolution.
- Controlled by App over wifi network.
- Surpassed now by the “Titan”, same company.

# Personal history

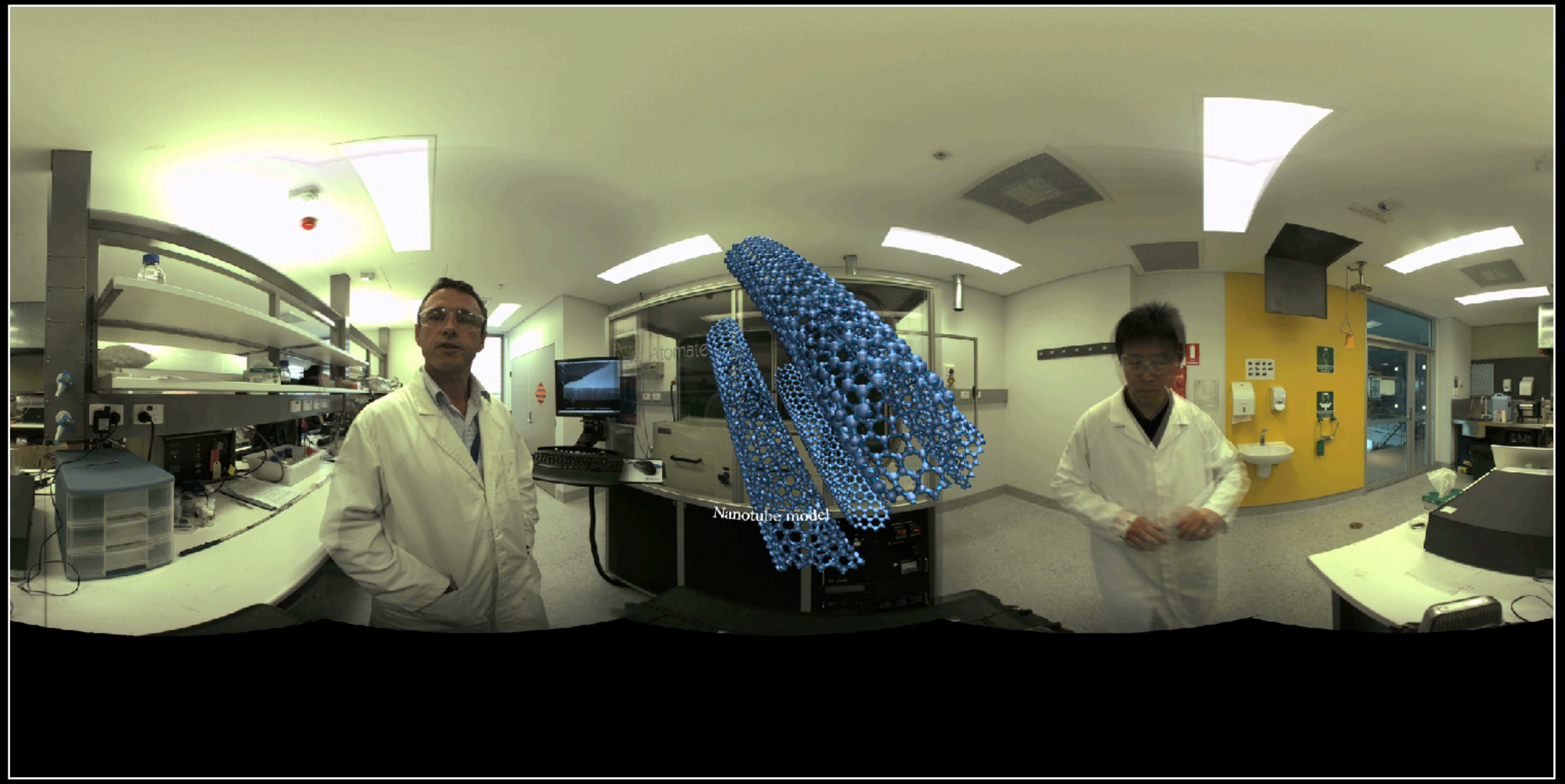
iCinema



Whirling Dervish, Turkiye

Karratha iron ore ship loader

Mah Meri, Malaysia



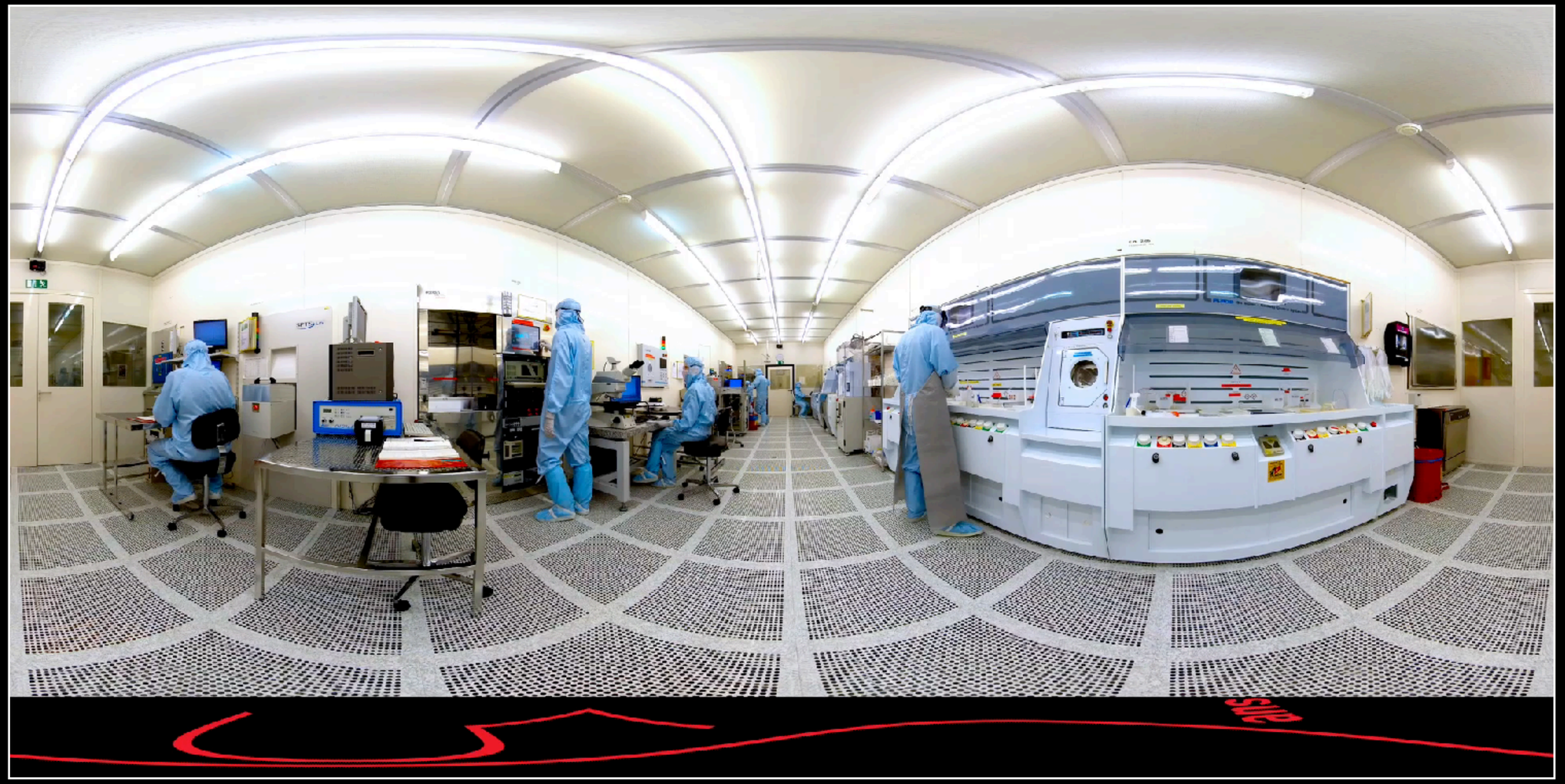

Nanotechnology, Wollongong

Sheep shearing, Barossa valley

Pig farming in Hong Kong

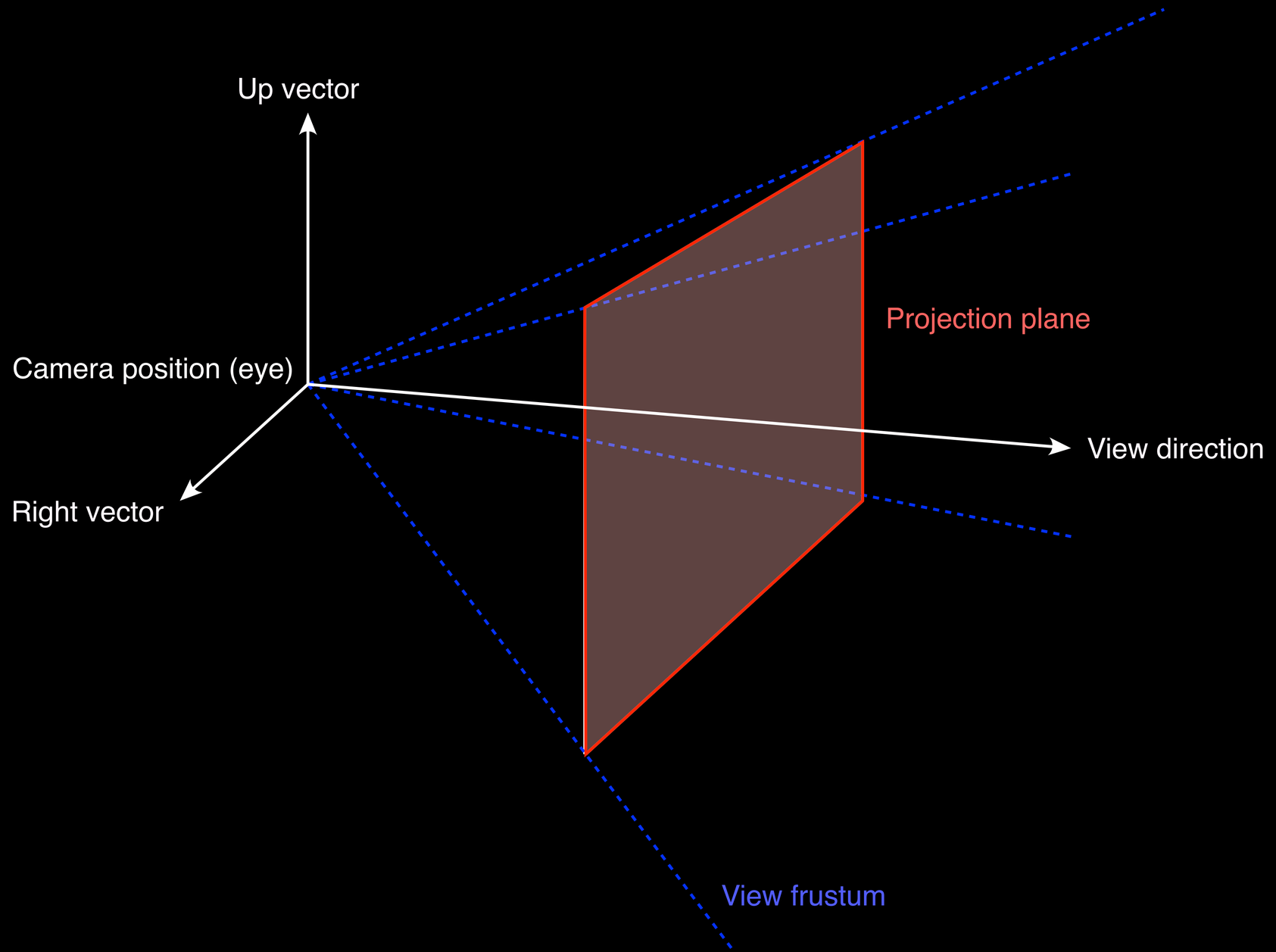
Sahet-Jetavana, India

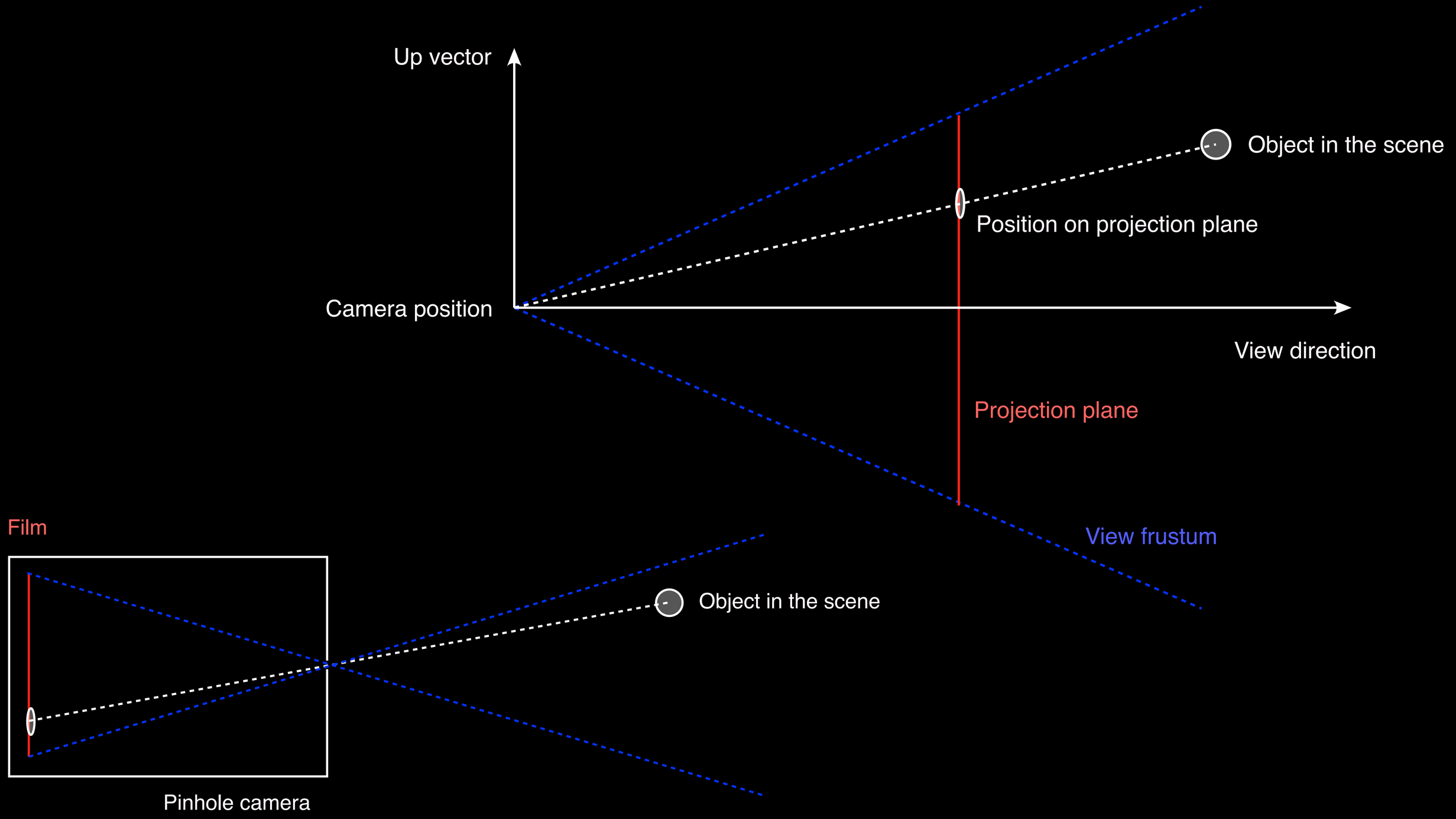
Clothing Buddha, India

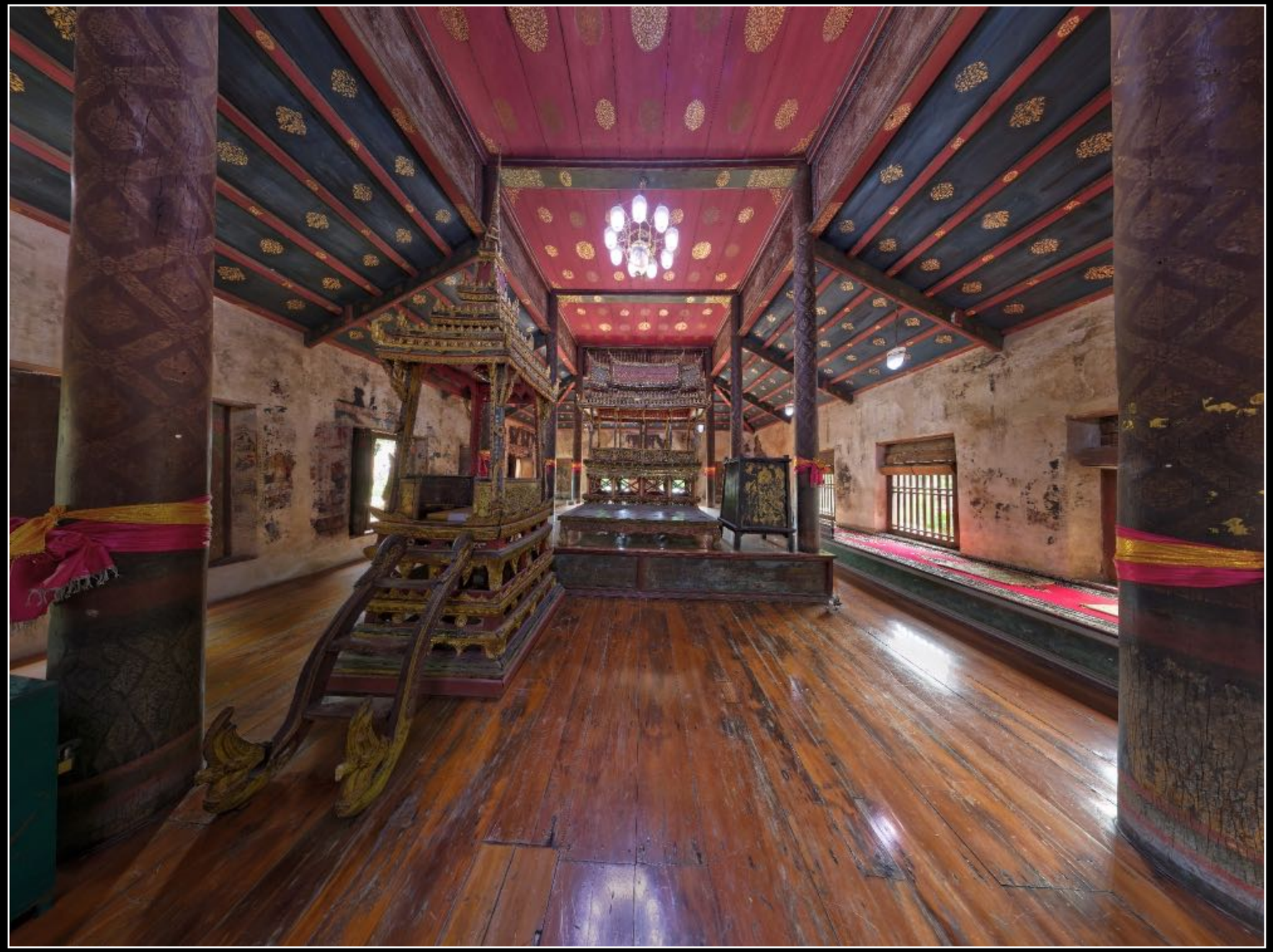


Micro and Nano Technology, EPFL, Switzerland

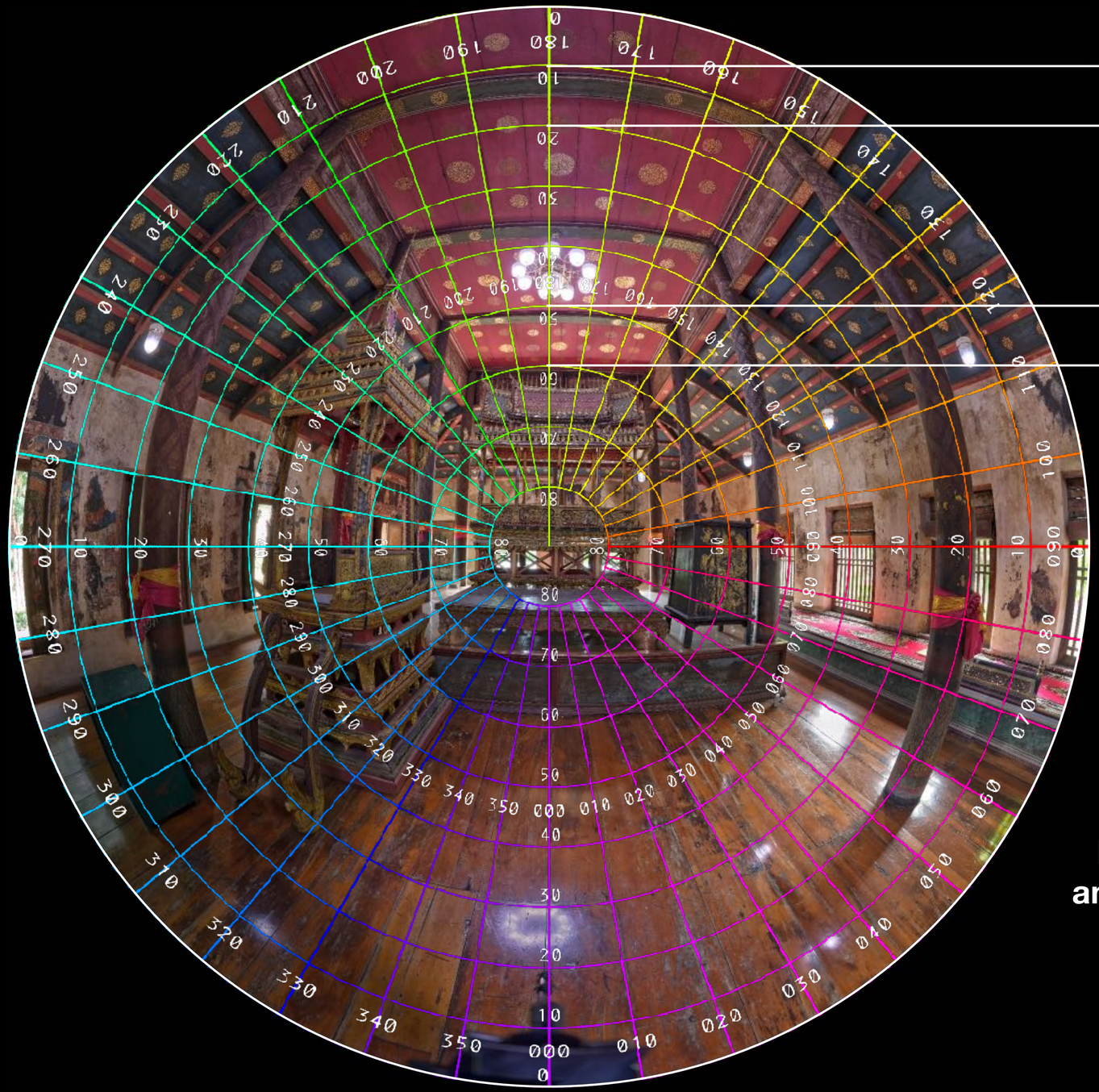
# Image projections - Perspective




Up vector
Object in the scene
Position on projection plane
Camera position
View direction
Projection plane
View frustum
Film
Object in the scene
Pinhole camera



# Image projections - Fisheye



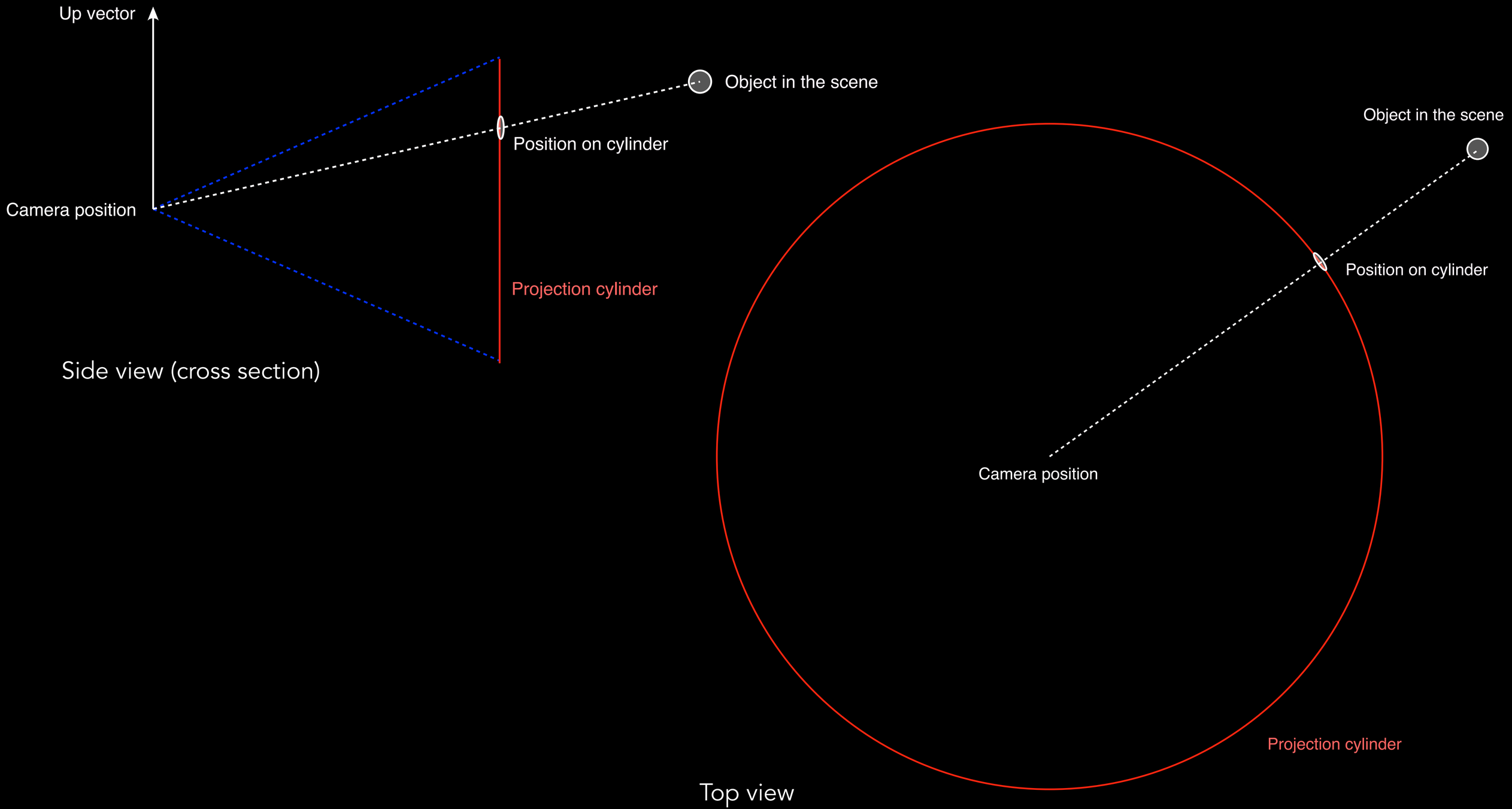
10 degrees

10 degrees

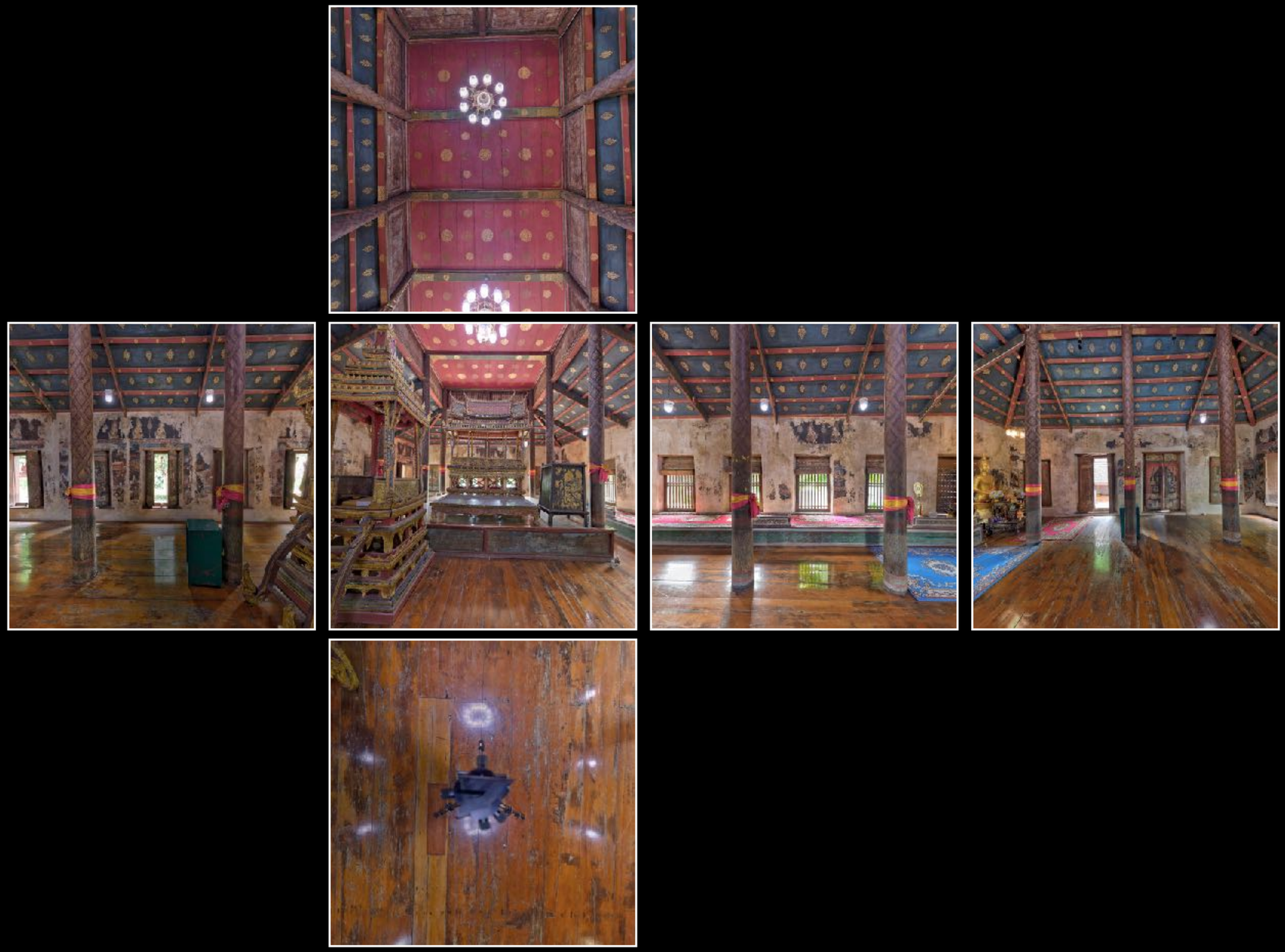
Equal radial distances correspond to equal angles of corresponding vector into the scene

# Image Projections - Cylindrical panorama

360 degrees


Up vector
Object in the scene
Position on cylinder
Camera position
Projection cylinder
Side view (cross section)
Object in the scene
Position on cylinder
Camera position
Projection cylinder
Top view

# Image projections - Cubemaps

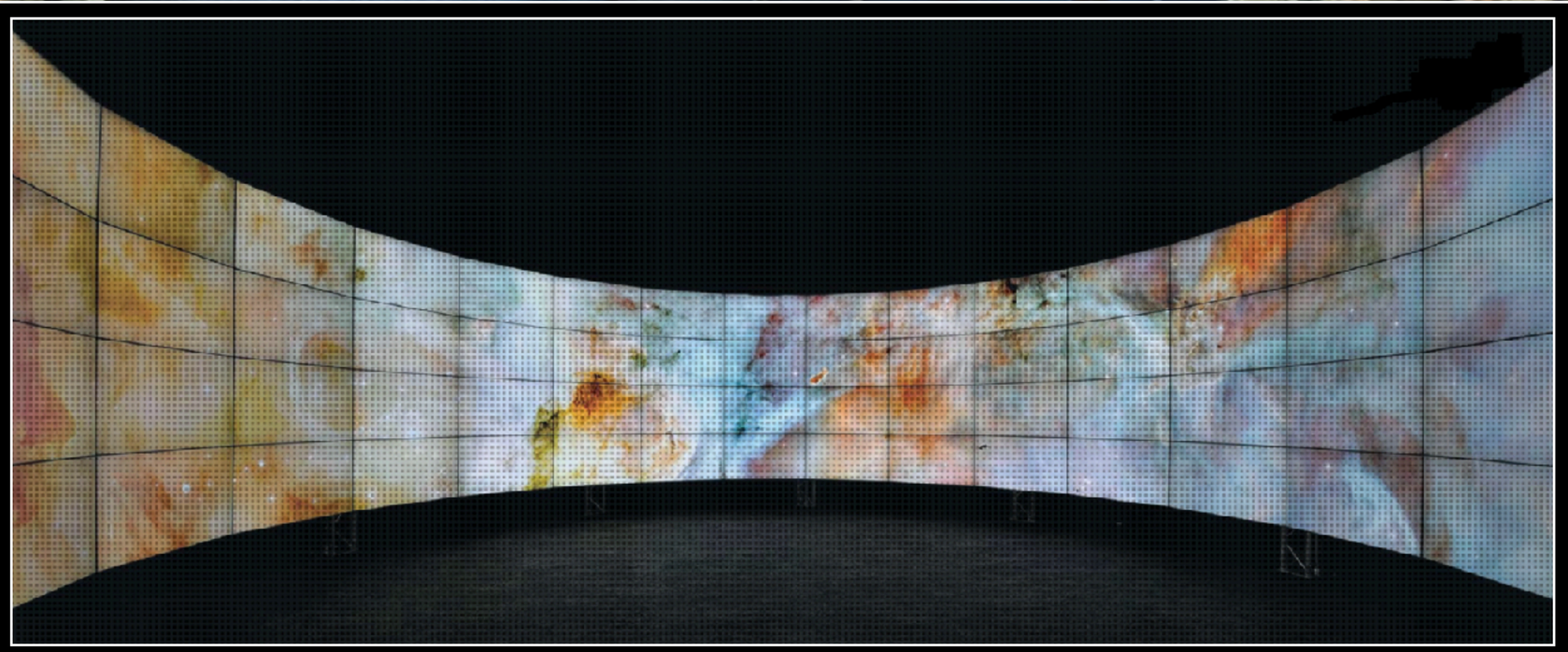


# Image Projections - Equirectangular

180 degrees

360 degrees

# Display environments

University of the Sunshine Coast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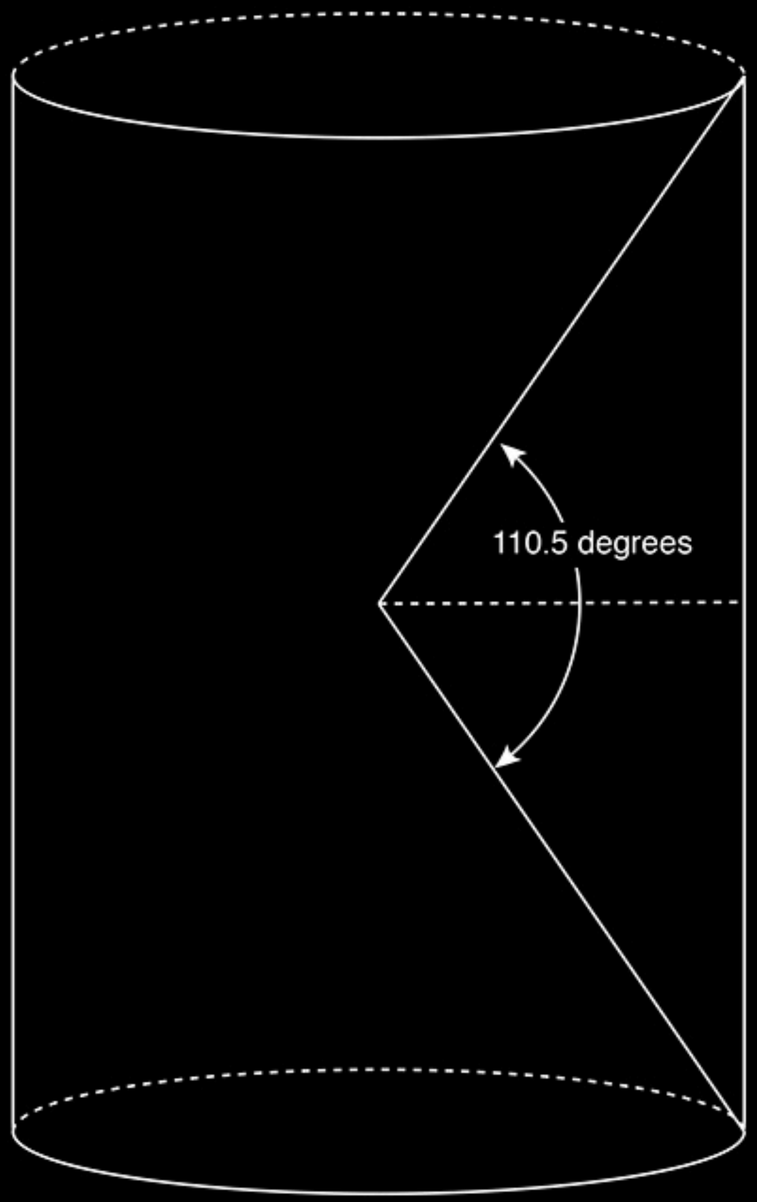
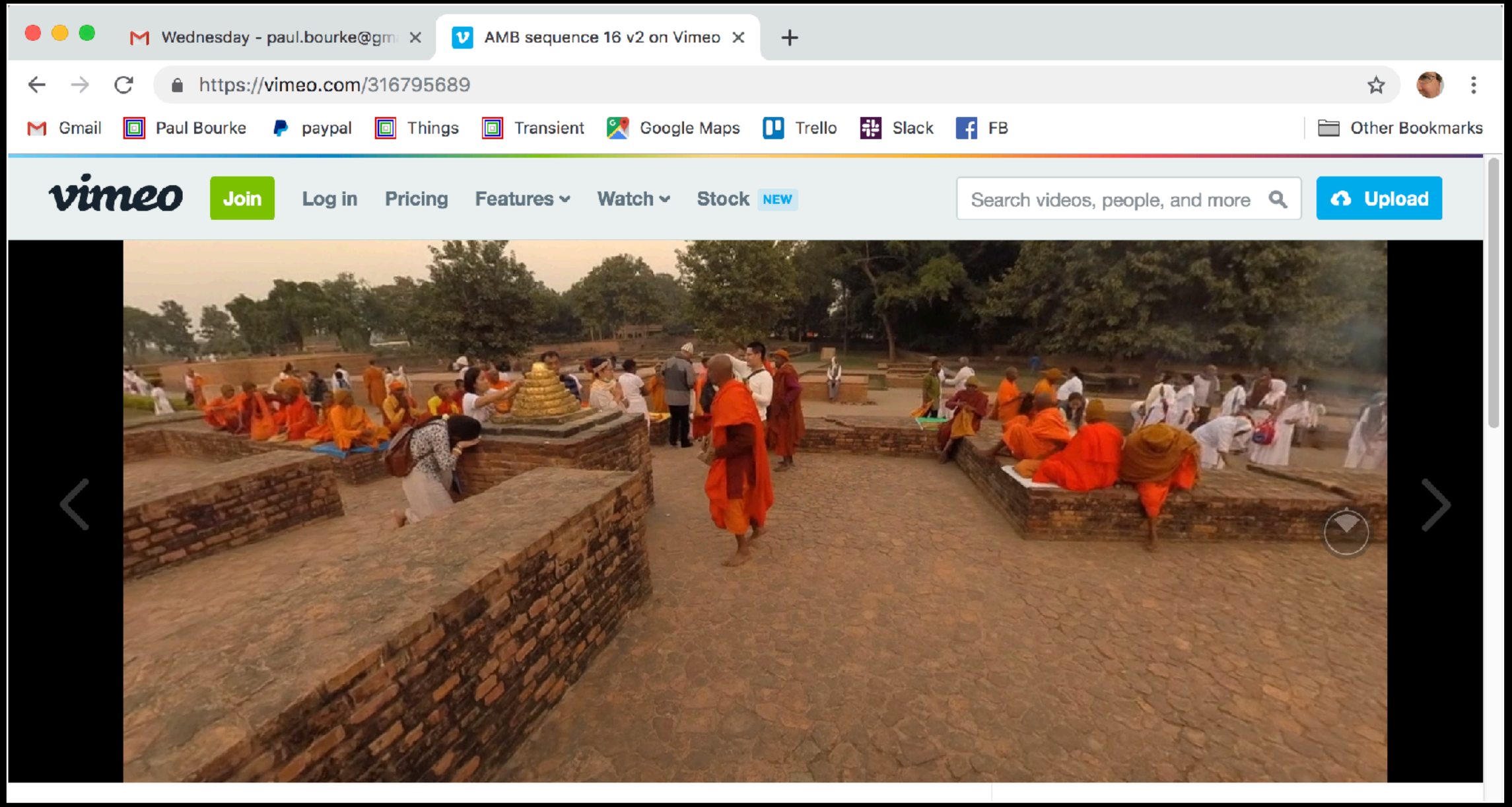

110.5 degrees


coles

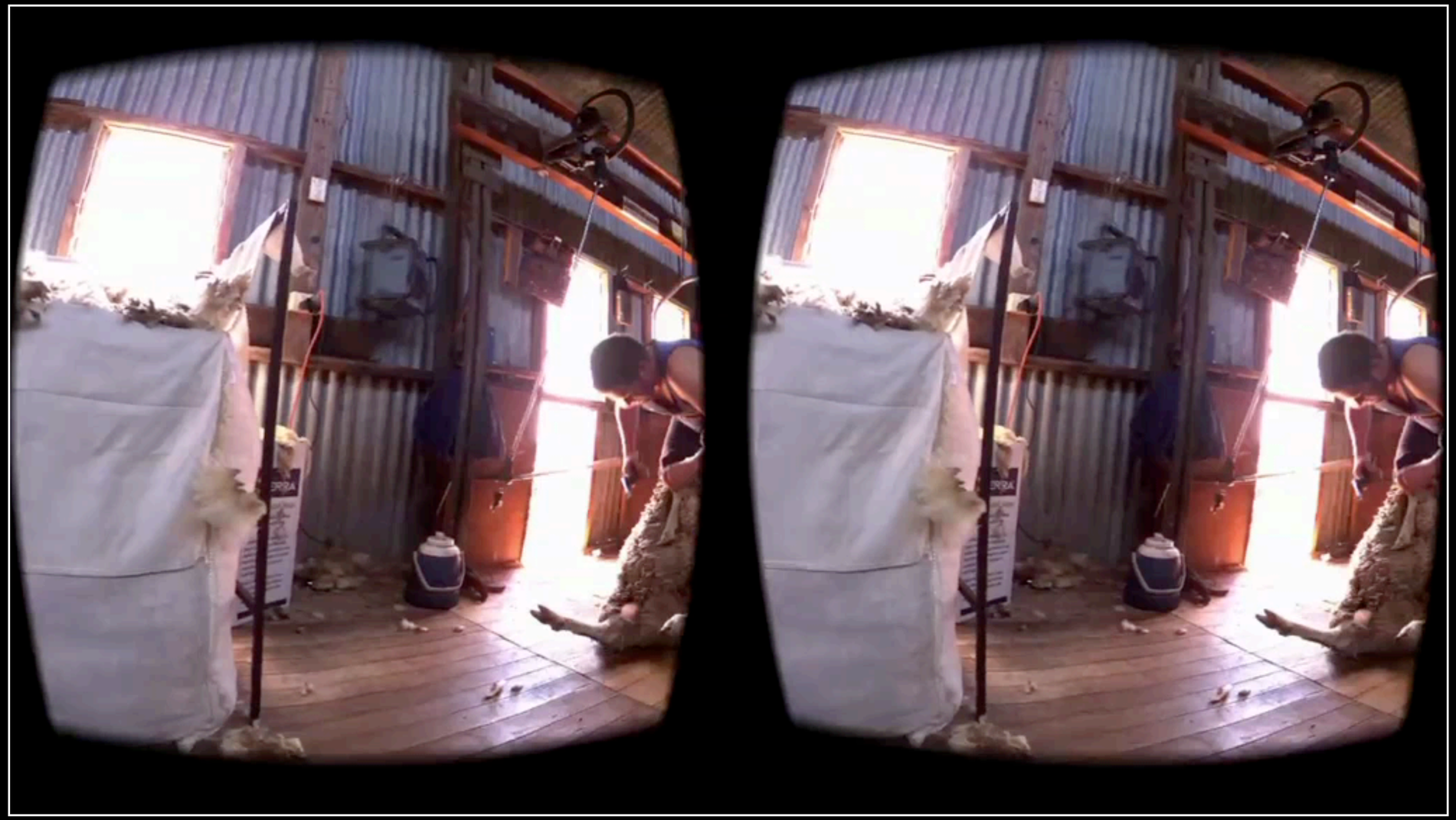
# Domes


Fit for Life
TREADMILLS

# Perspective



# Head mounted displays



# Camera summary




SHOCKPROOF 2m/6.6ft
4K
WiFi


RICOH


Insta360 Air


00:06
5.7K 30 FPS


4K UHD


5.3K 30
00:01


MODE
OK
NFC
Wi Fi
SPLASH PROOF

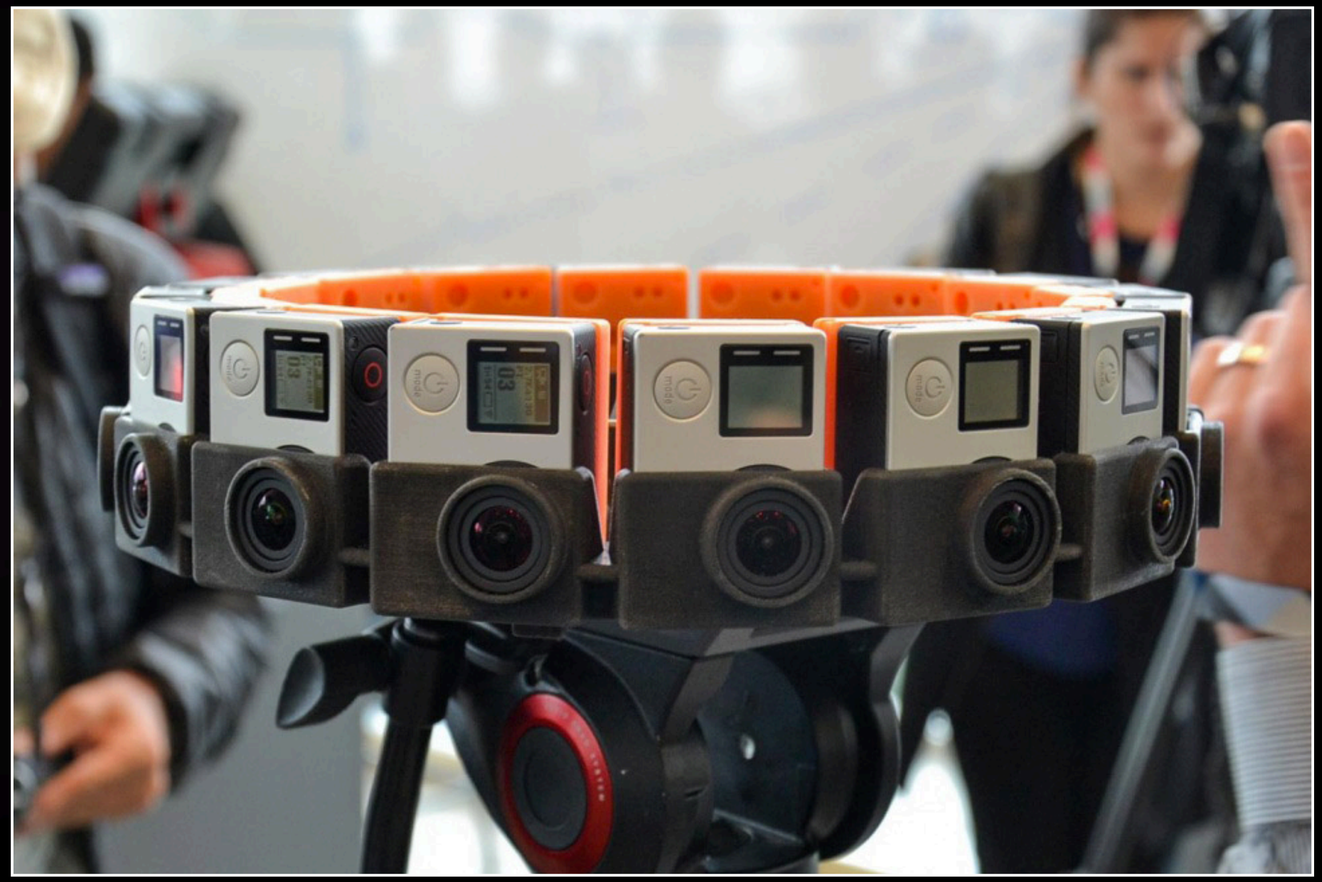

KANDAO

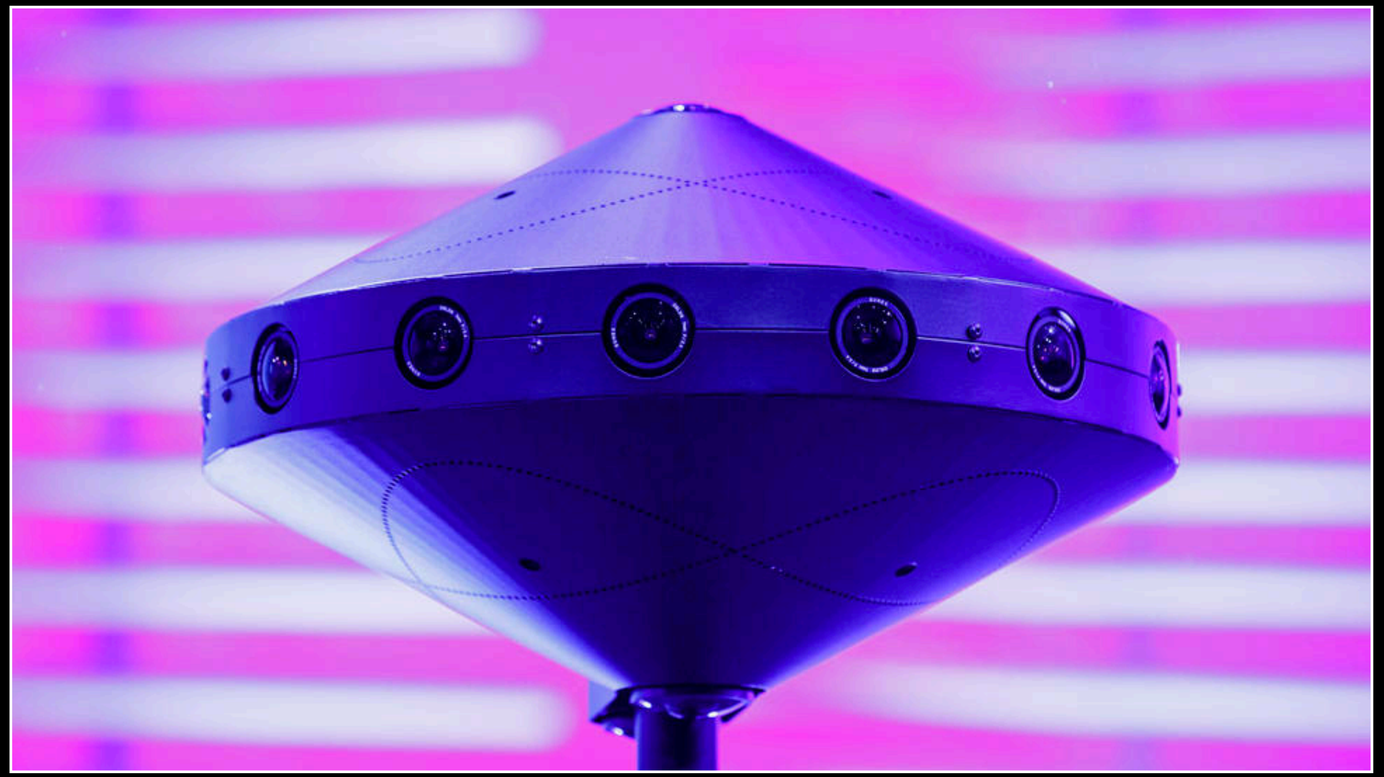

VUZE


yi


F4


JAUNT



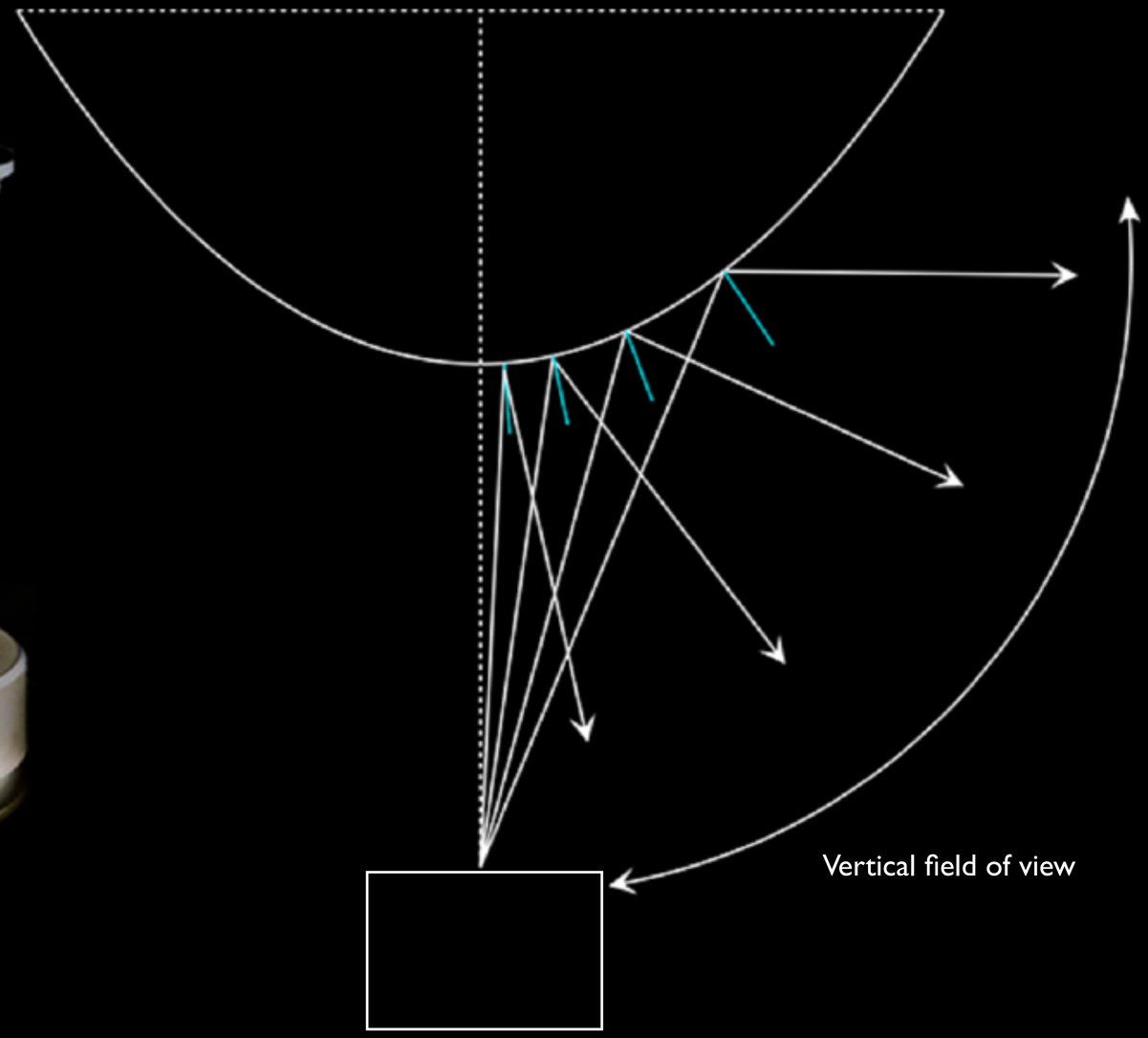


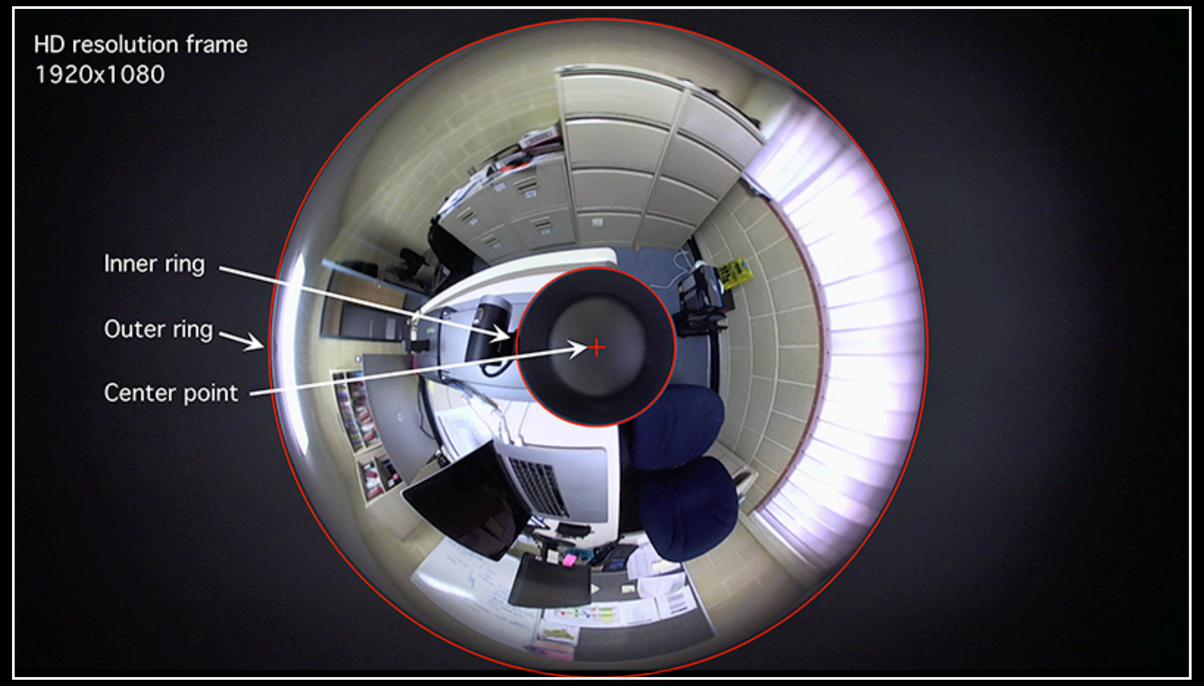
Ladybug-3

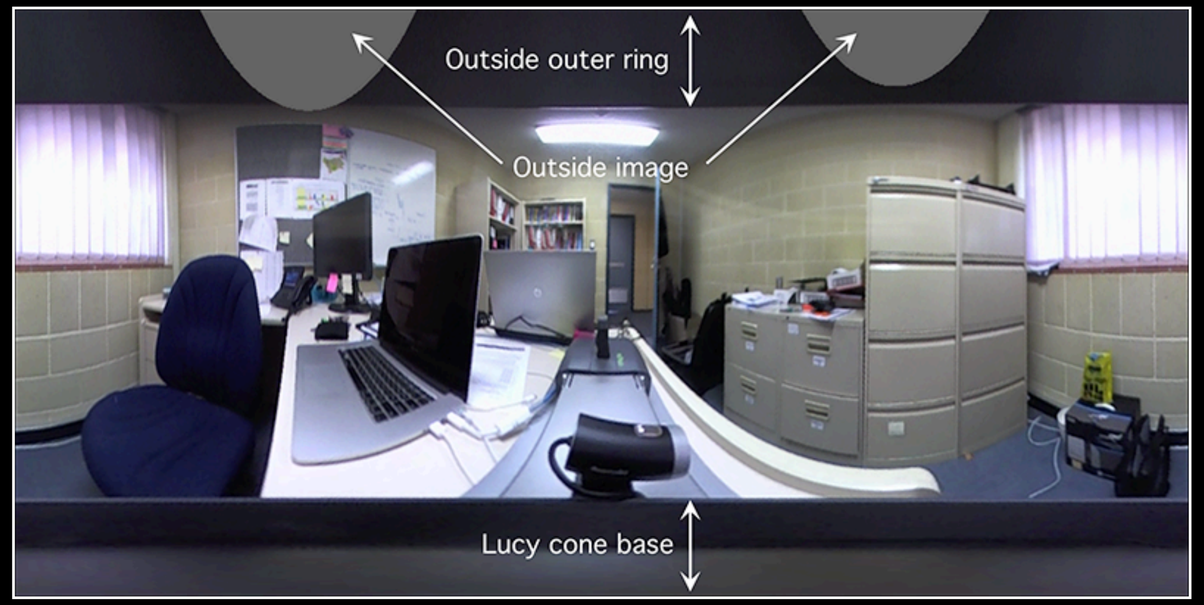
Insta360Pro-2

Garmin Virb

# Single camera




HD resolution frame
1920x1080
Inner ring
Outer ring
Center point


Outside outer ring
Outside image
Lucy cone base


pano pro
a virtual tour in just one photo
www.pano-pro.com

Entaniya 250 degree fisheye

# Single camera merits

Advantages:

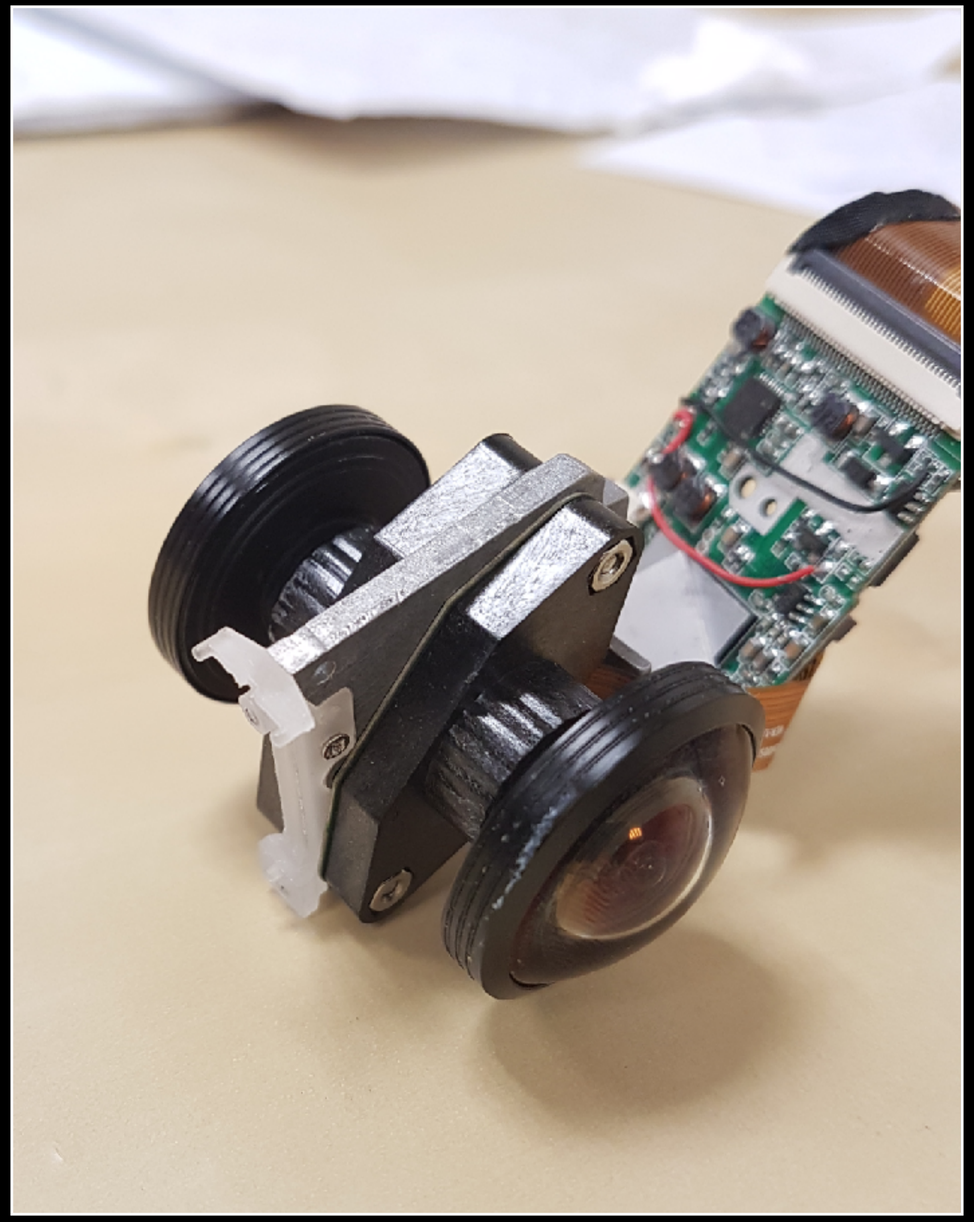
Simple - Small - No blending - No parallax errors

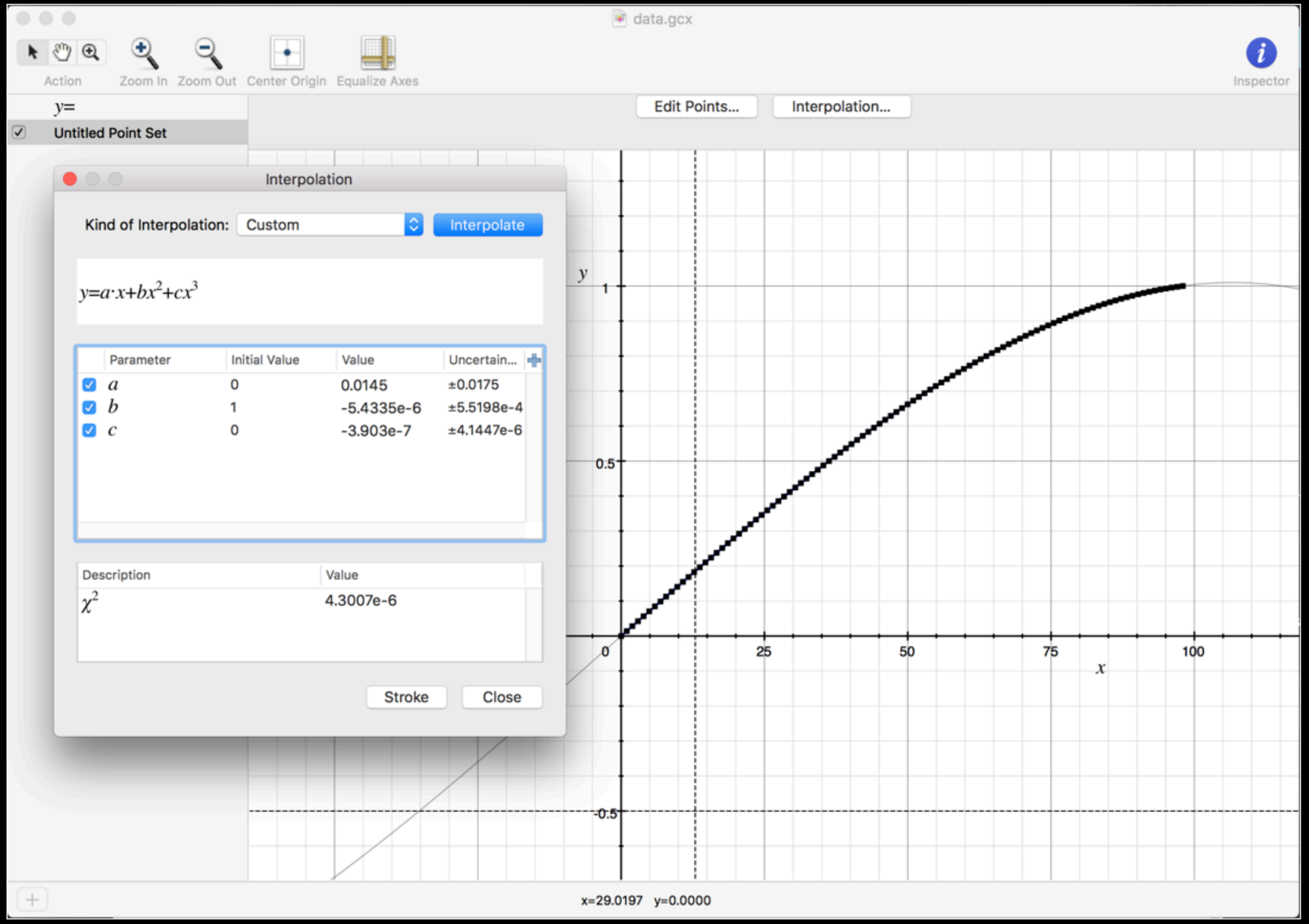
Disadvantages:

Doesn’t capture whole 360x180 field of view

Doesn’t scale!

# Dual cameras




data.gcx
Action
Zoom In
Zoom Out
Center Origin
Equalize Axes
Inspector
y=
Untitled Point Set
Edit Points...
Interpolation...
Interpolation
Kind of Interpolation: Custom
Interpolate
y=a·x+bx²+cx³
Parameter
Initial Value
Value
Uncertain...
a 0 0.0145 ±0.0175
b 1 -5.4335e-6 ±5.5198e-4
c 0 -3.903e-7 ±4.1447e-6
Description
Value
χ² 4.3007e-6
Stroke
Close
y
1
0.5
0
-0.5
25
50
75
100
x
x=29.0197 y=0.0000

# Dual camera merits

Advantages:

Small - Single blend line - Higher resolution than single camera

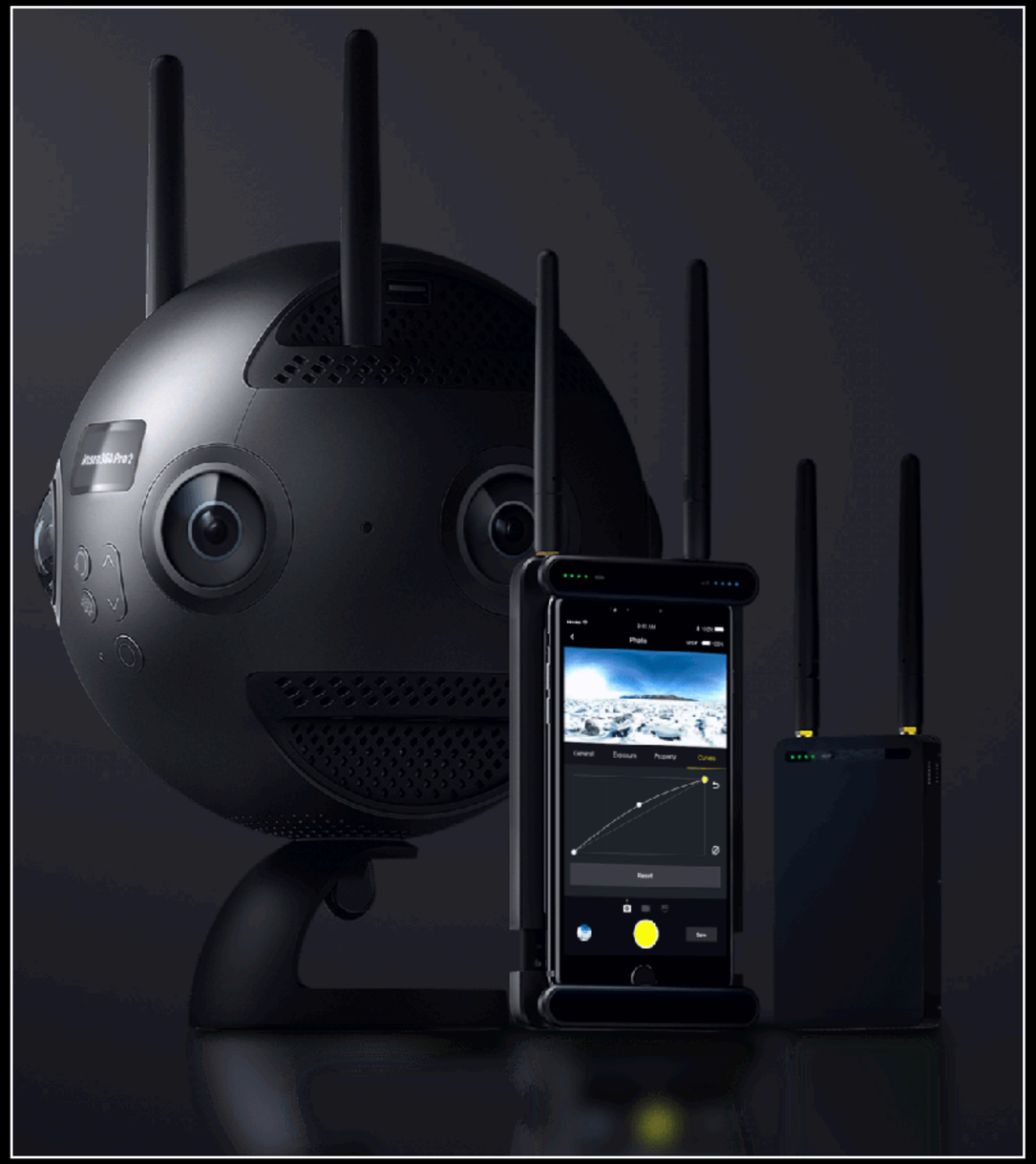
Disadvantages:

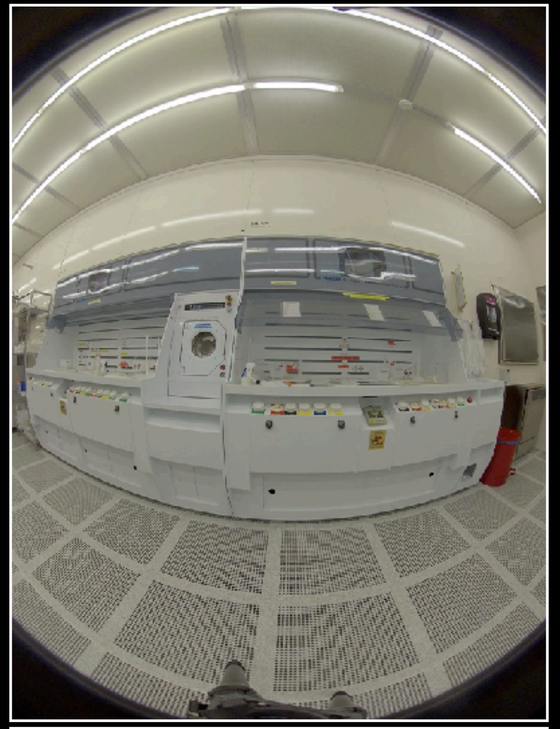
Doesn’t scale!

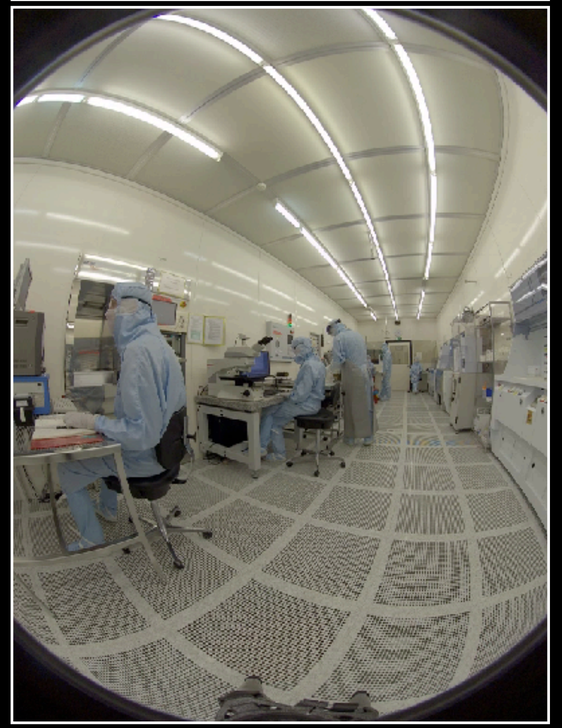
Cannot support stereoscopic 3D

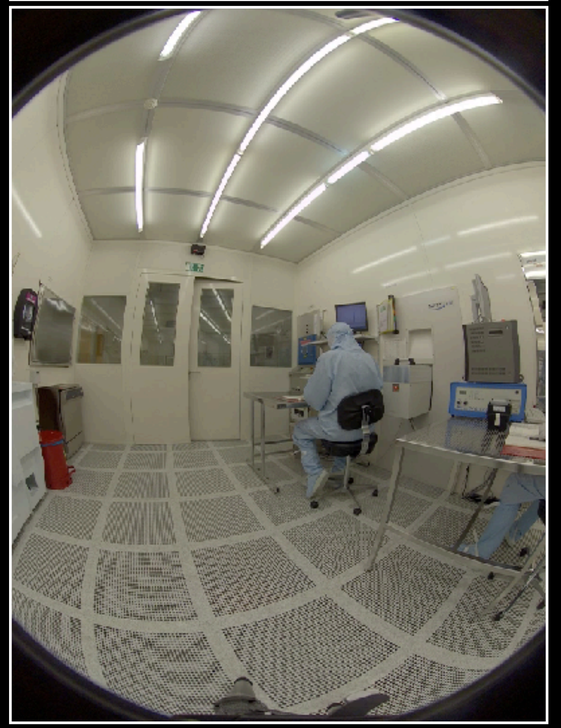
# Multiple cameras (>2)

- Will focus on the Insta360Pro2
- 6 Camera/lenses
- One microSD card per camera
- Maximum resolution 7680 x 3840 @ 30fps
- Long range live feed and control
- Built in stabilisation

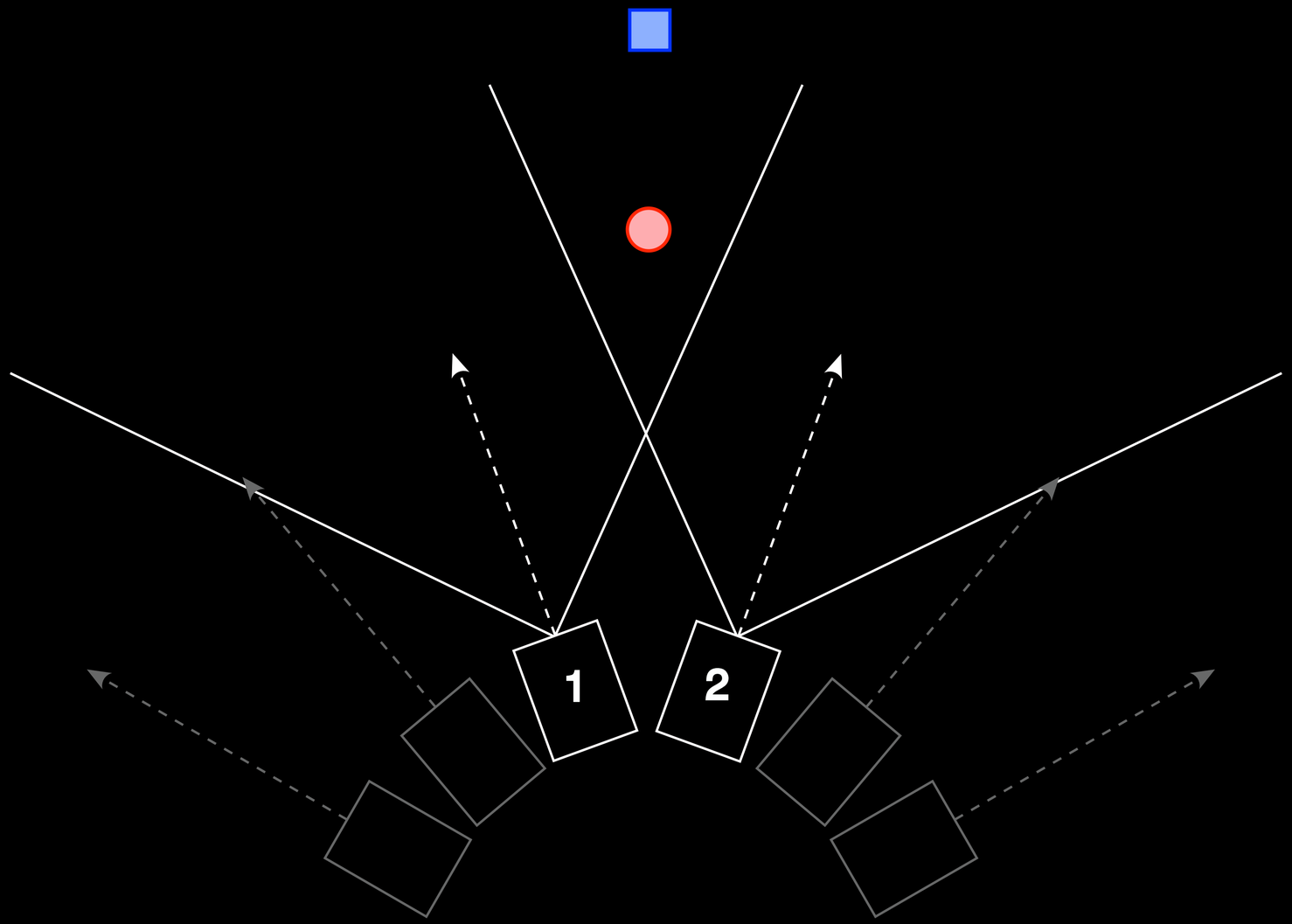


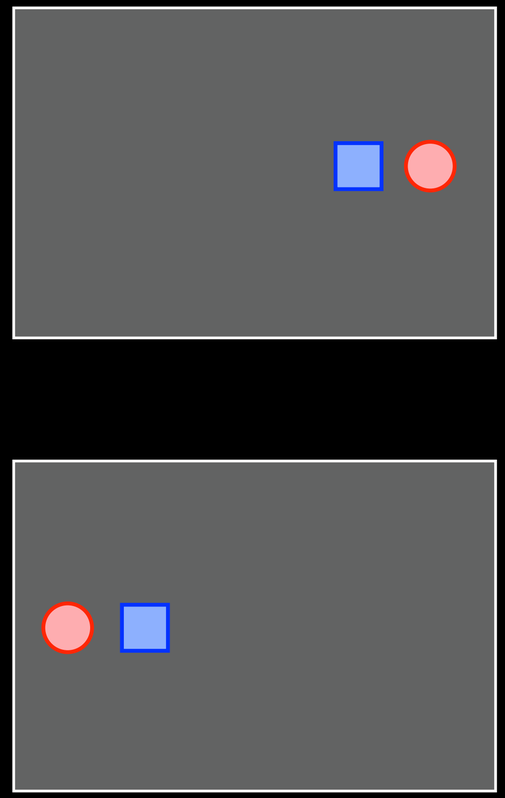



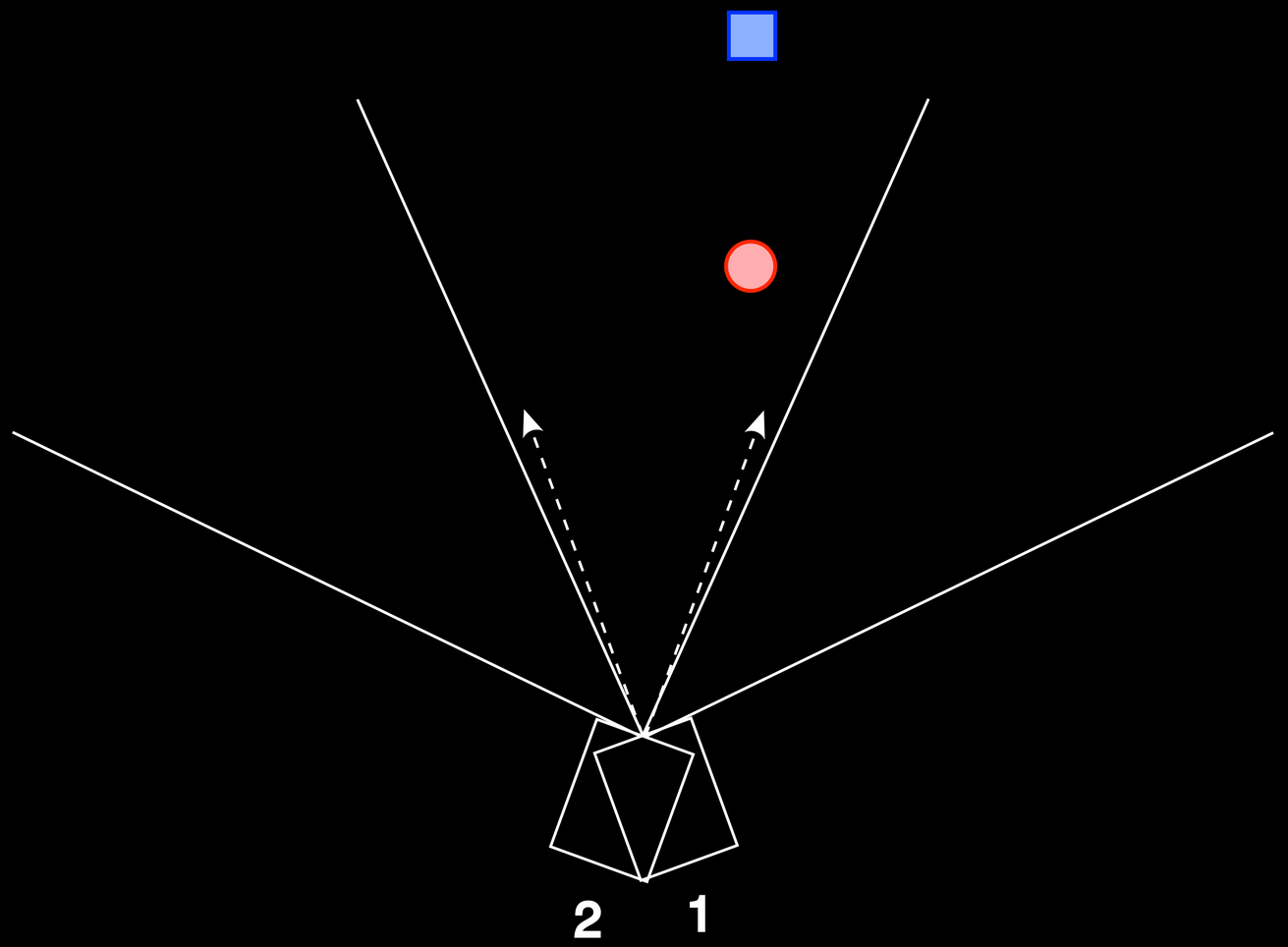


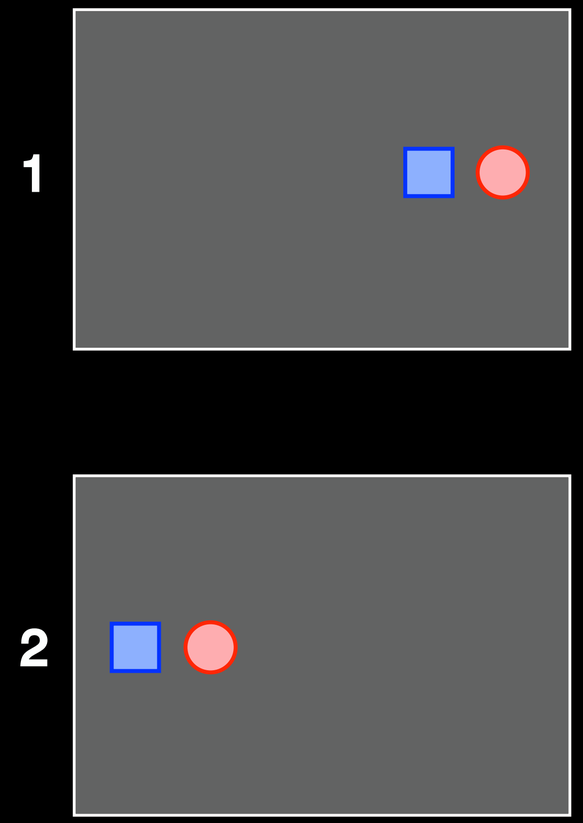


# The fundamental problem

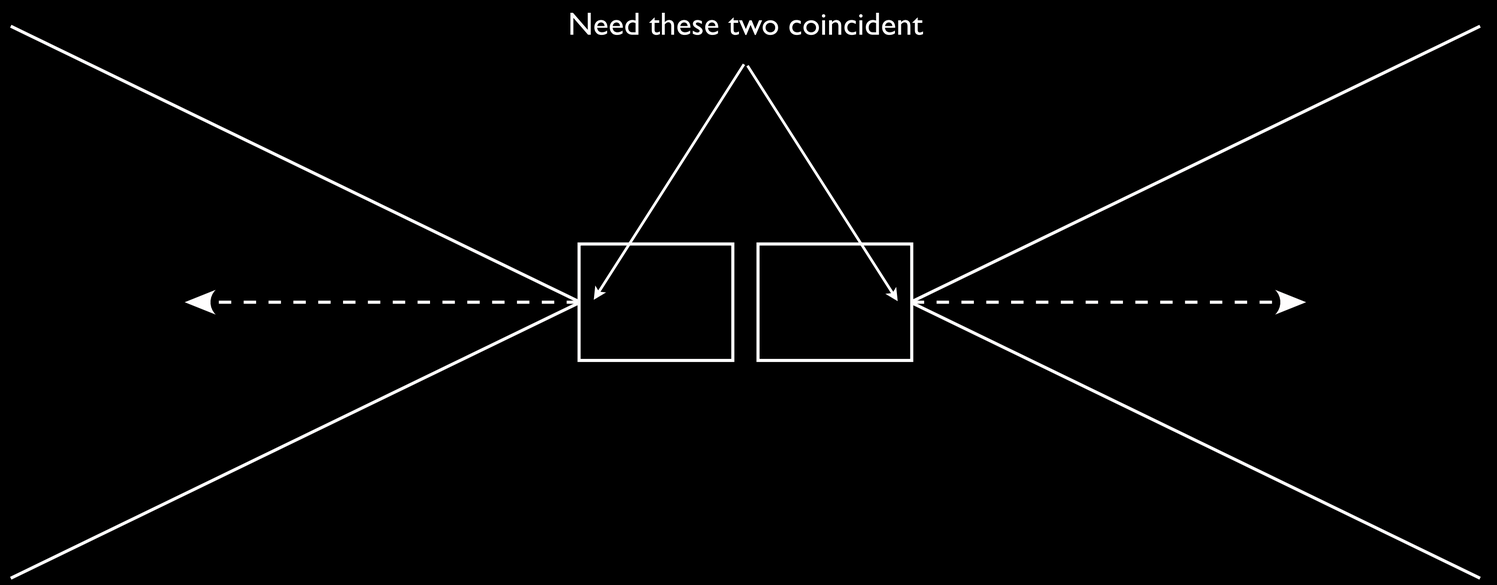


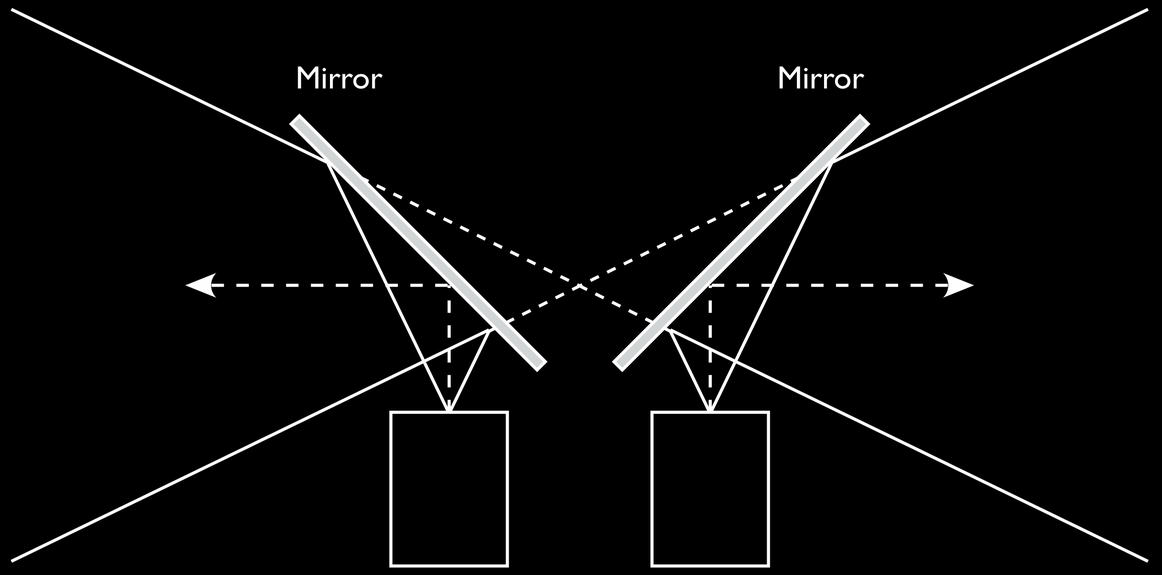



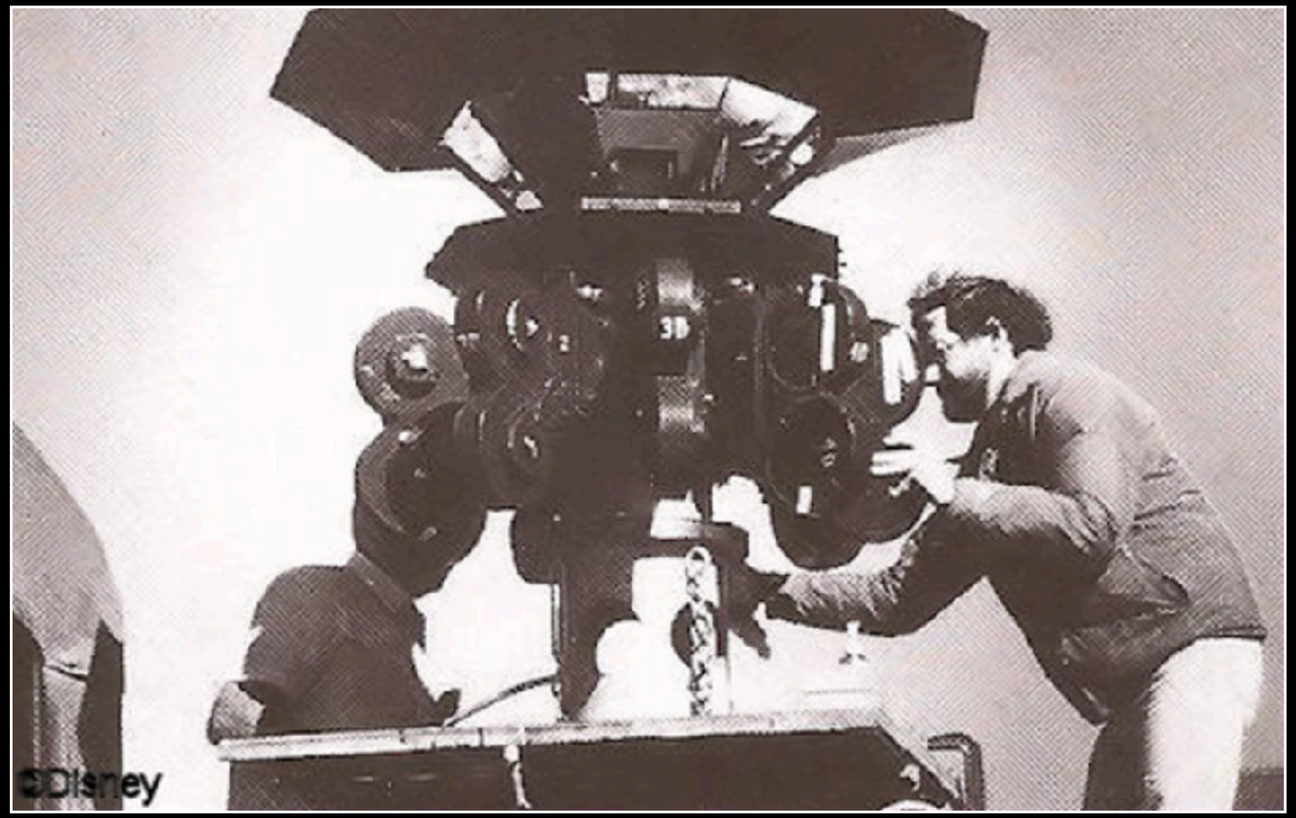

2
1


1
2

# Solutions - Mirrors

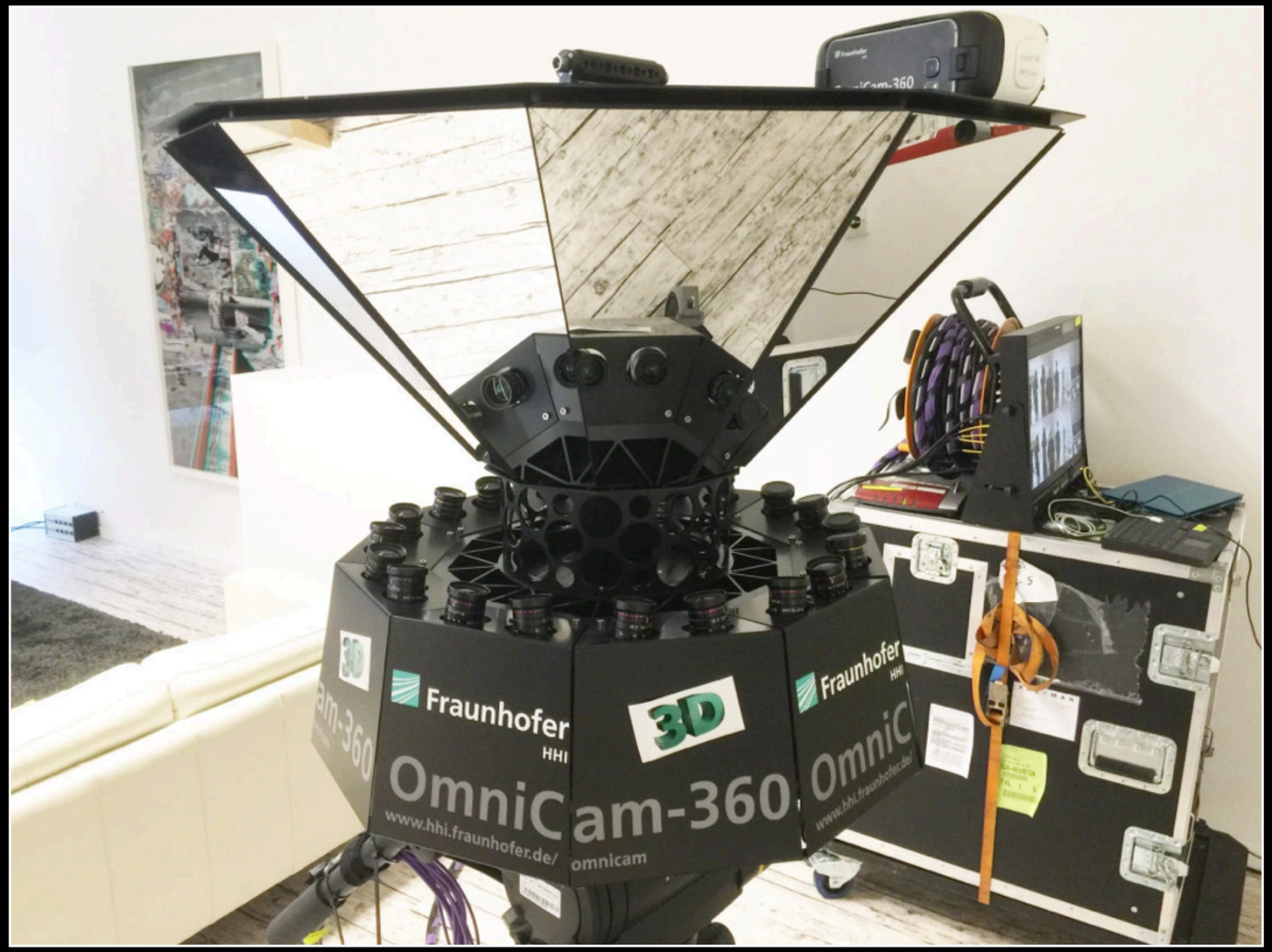






Circlorama camera #2 (Disney)


Fraunhofer
HHI
OmniCam-360
www.hhi.fraunhofer.de/omnicam
3D


2
17
1

(12) **United States Patent**
**Masuda et al.**

(54) **IMAGING SYSTEM AND IMAGING OPTICAL SYSTEM**

(75) Inventors: **Kensuke Masuda**, Kawasaki (JP); **Noriyuki Terao**, Sendal (JP); **Yoshiaki Irino**, Kawasaki (JP); **Tomonori Tanaka**, Yokohama (JP); **Nozomi Imae**, Yokohama (JP); **Toru Harada**, Yokohama (JP); **Hirokazu Takenaka**, Kawasaki (JP); **Hideaki Yamamoto**, Yokohama (JP); **Satoshi Sawaguchi**, Yokohama (JP); **Hiroyuki Satoh**, Kawasaki (JP)

(73) Assignee: **RICOH COMPANY, LTD.**, Tokyo (JP)

(10) **Patent No.: US 9,201,222 B2**
(45) **Date of Patent: Dec. 1, 2015**

USPC ..... 348/36, 335; 359/725
See application file for complete search history.

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7,154,551 B2 * 12/2006 Kuriyama et al. ..... 348/335

(Continued)

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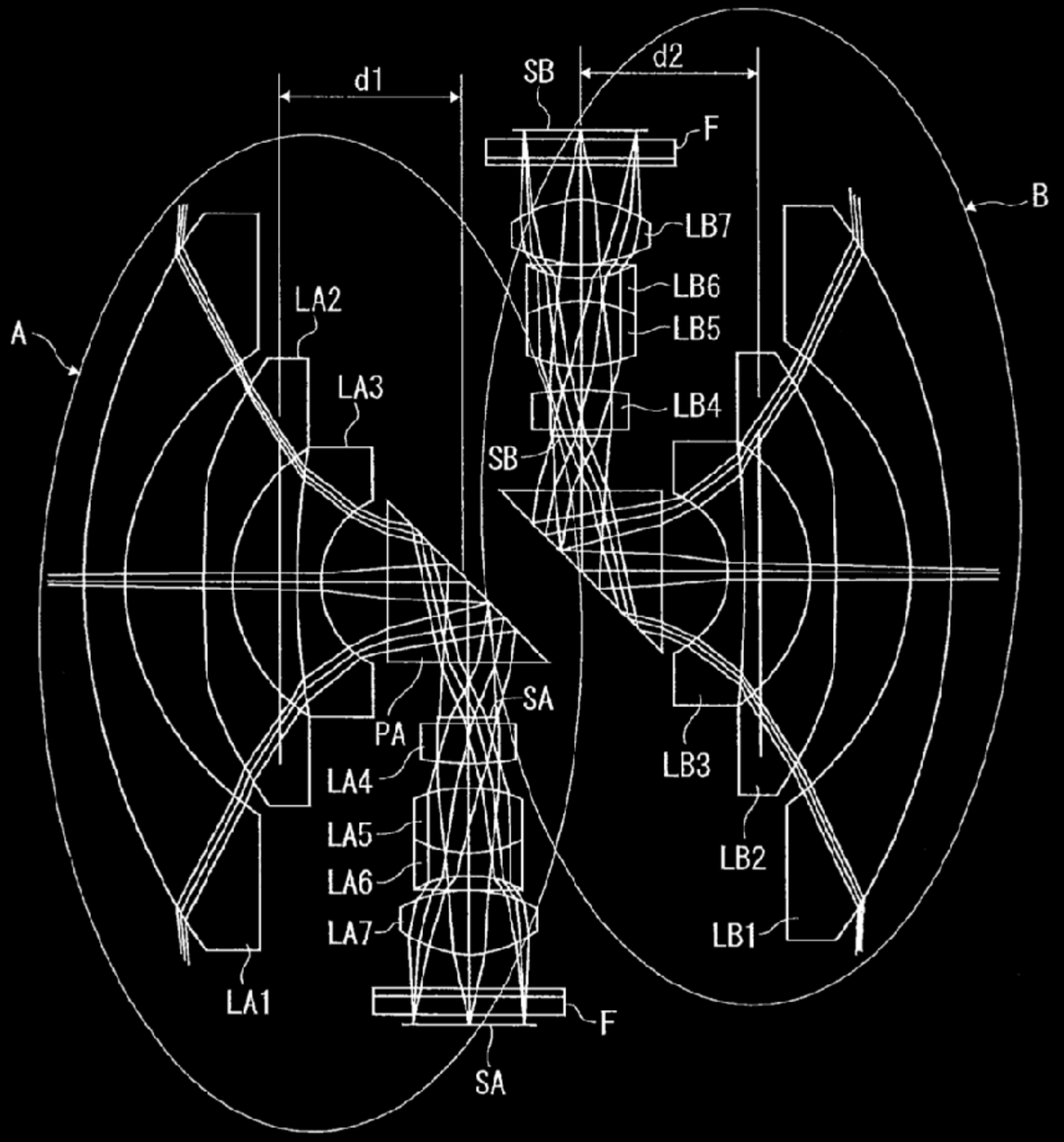
JP 2007-164079 6/2007

(Continued)

FIG. 1



# Solutions - Custom Optics

E01
E02
E03
E04
E05
V01
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V03
V04
V05
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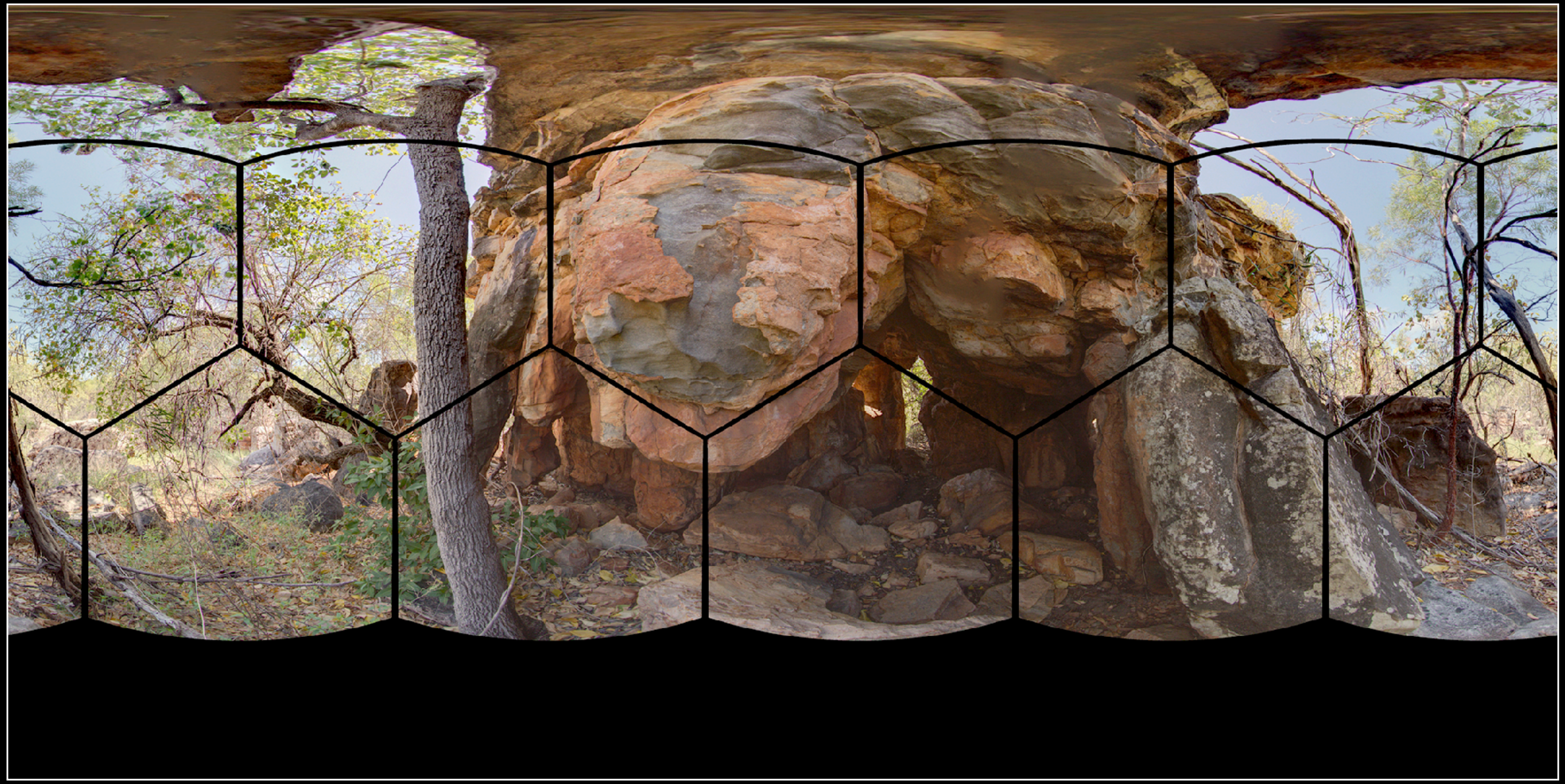
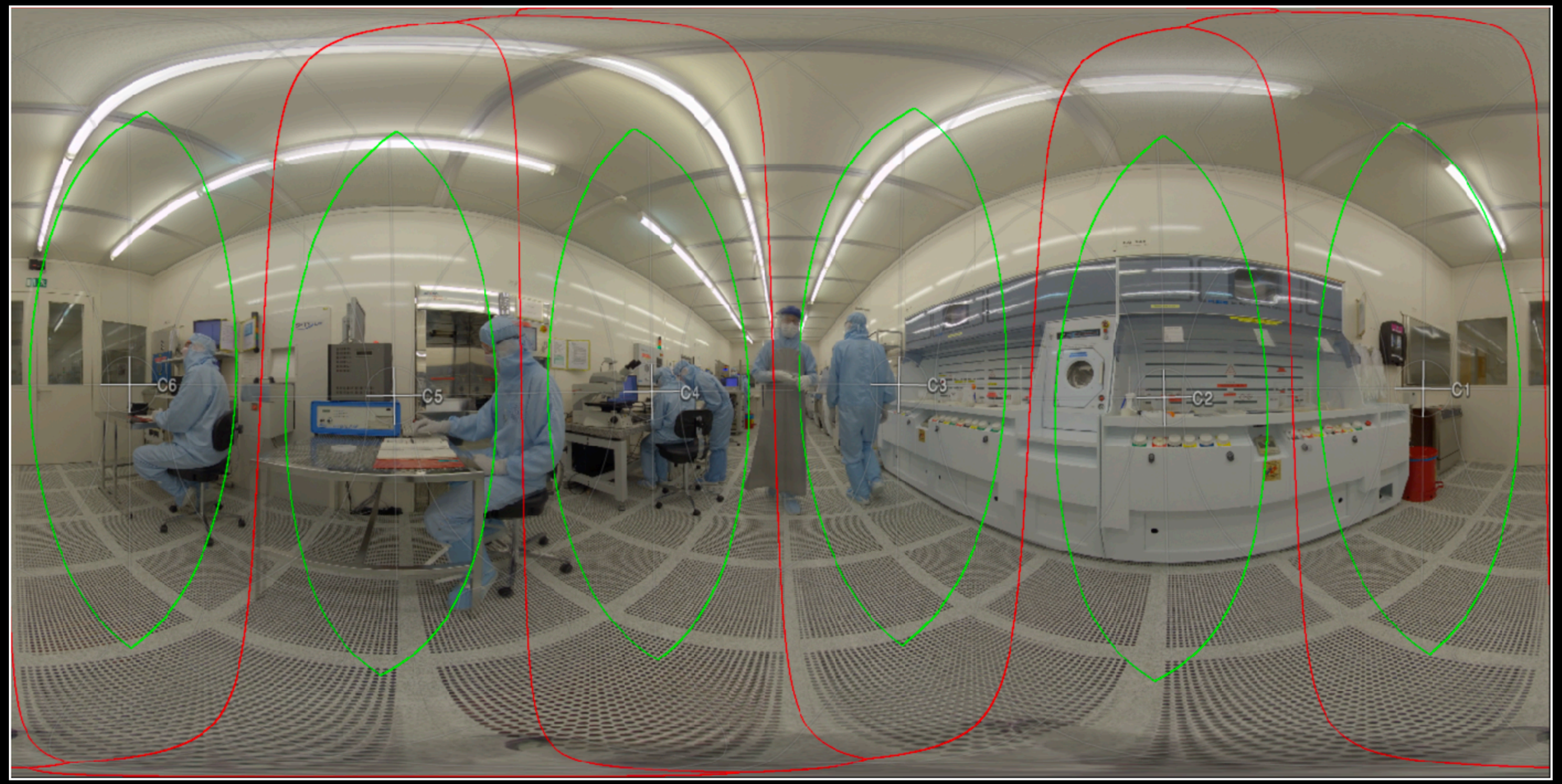
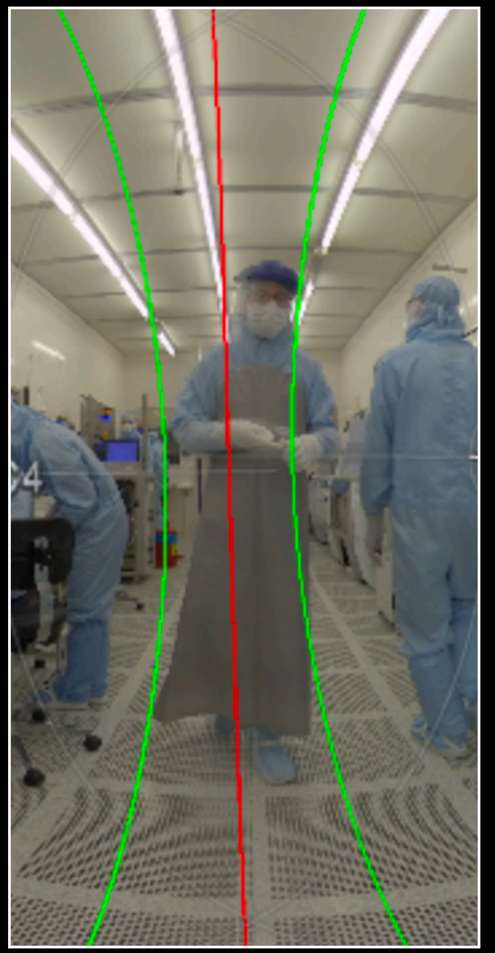


# Solutions - Optical Flow

- Tracks image content between frames and performs local warping to maintain continuity.
- Pretty much the standard solution today in all multiple camera rigs and associated software.
- Perhaps one of the leaders is MistakaVR.
- NOTE: It is not perfect, the parallax issue cannot always be corrected/hidden.


Mistika VR - epfl[epfl.vrenv] - 3840x1920 30.00 fps
Origin_1
Origin_2
Origin_3
Origin_4
Origin_5
Origin_6
Sync
Stitch
Color
Positions
Edge Points
00:02:48:24
Options
Use Optical Flow
Fill Holes
Black
Stitch Feathe
20.000
Convergence
0.000
Gamma Curve
ITU-BT 709 / ITU-BT 2020
Input Levels
Auto
Vertical Balan
Vignetting
Optical Flow
Camera Defaults
Input Cameras
Edge Points
Output Camera
Mapping
LatLong
Yaw:
152.000
Pitch:
0.000
Roll:
0.000
Focal Length
Offset X:
Offset Y:
Undistort a:
Undistort b:
Undistort c:


C6
C5
C4
C3
C2
C1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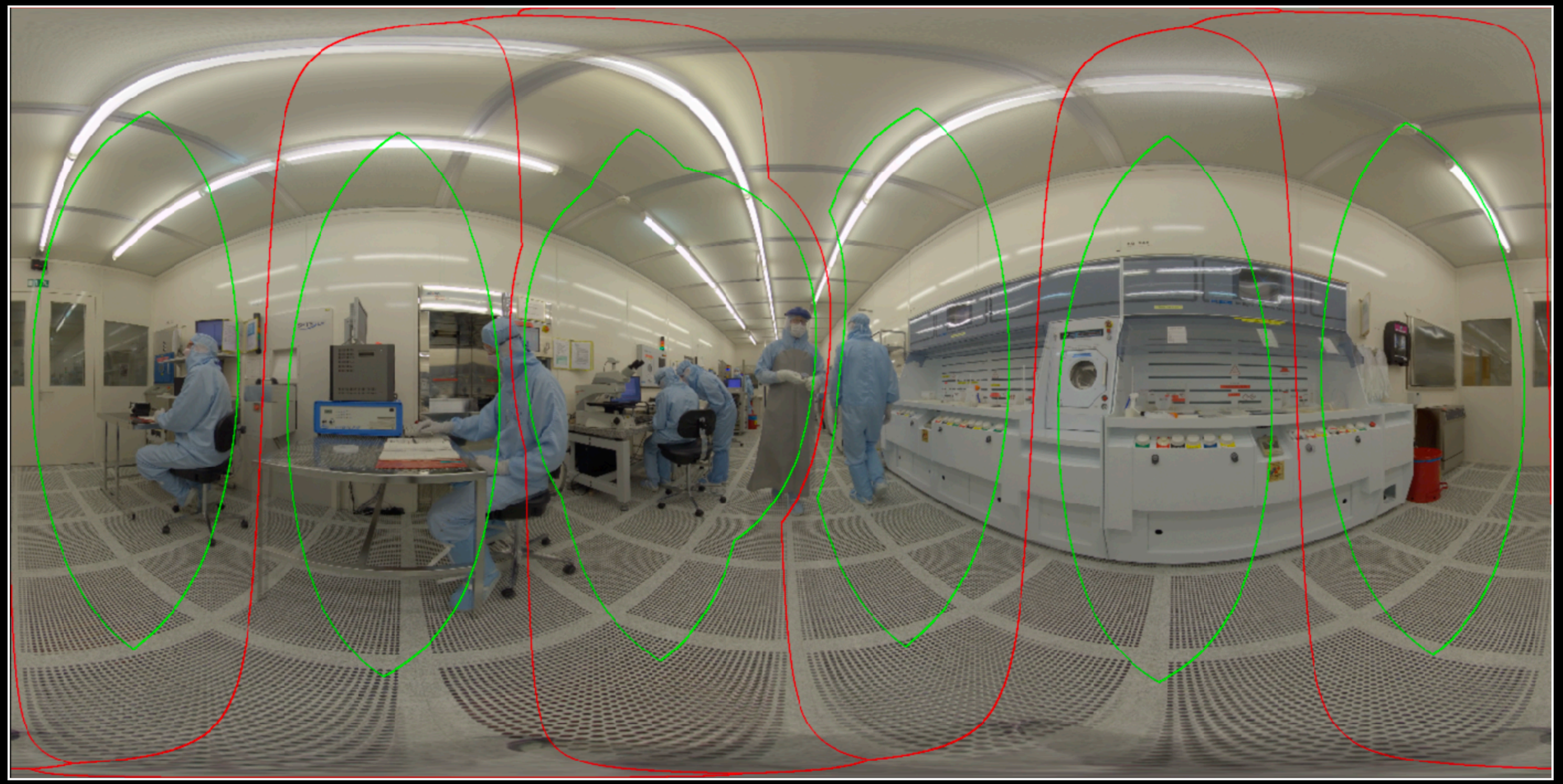
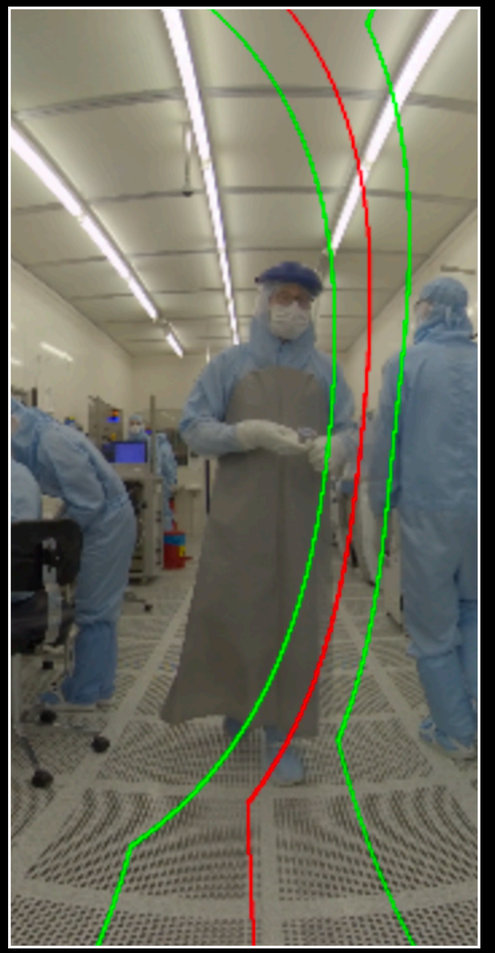




# Miscellaneous topics

- Resolution
- Zooming
- Wrapping
- Non-linear space
- Dynamic range
- Hiding
- Stereoscopic 360 video

# State of the art: Resolution

4K

State of the art circa 2010
Commodity cameras per 2015

5.7K

Current commodity cameras

8K

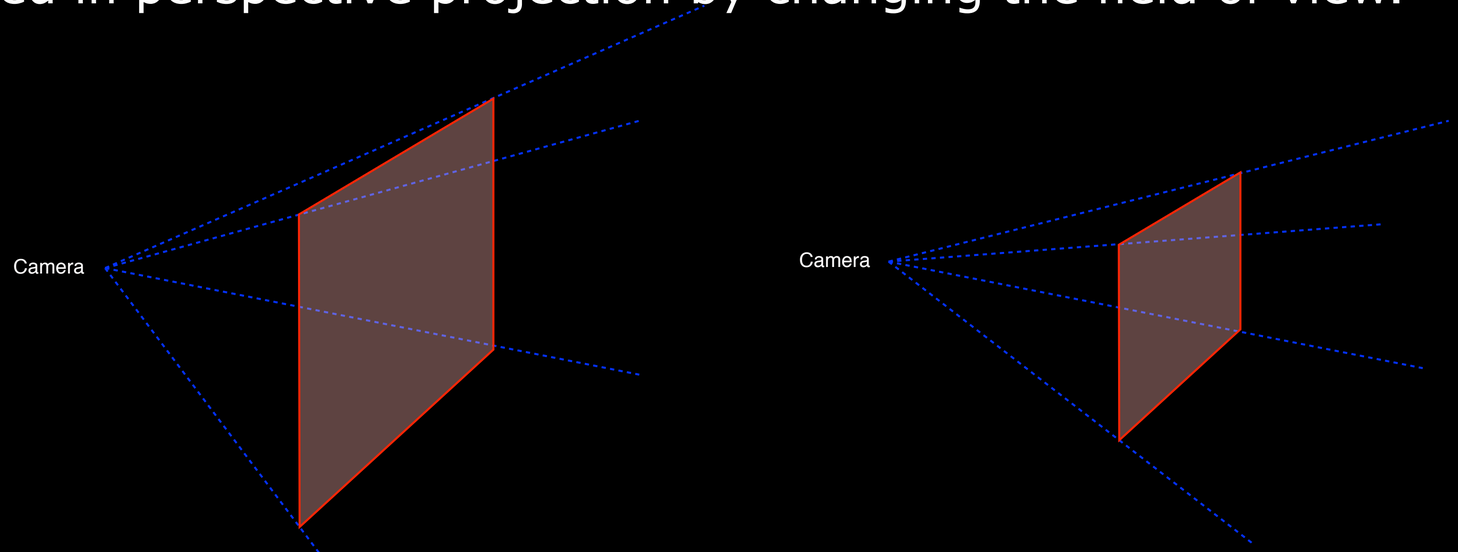
Current state of the art

11K

Leading cameras

# Miscellaneous topics - Zooming

- There is no such thing as a zoom.
  Zoom is achieved in perspective projection by changing the field of view.



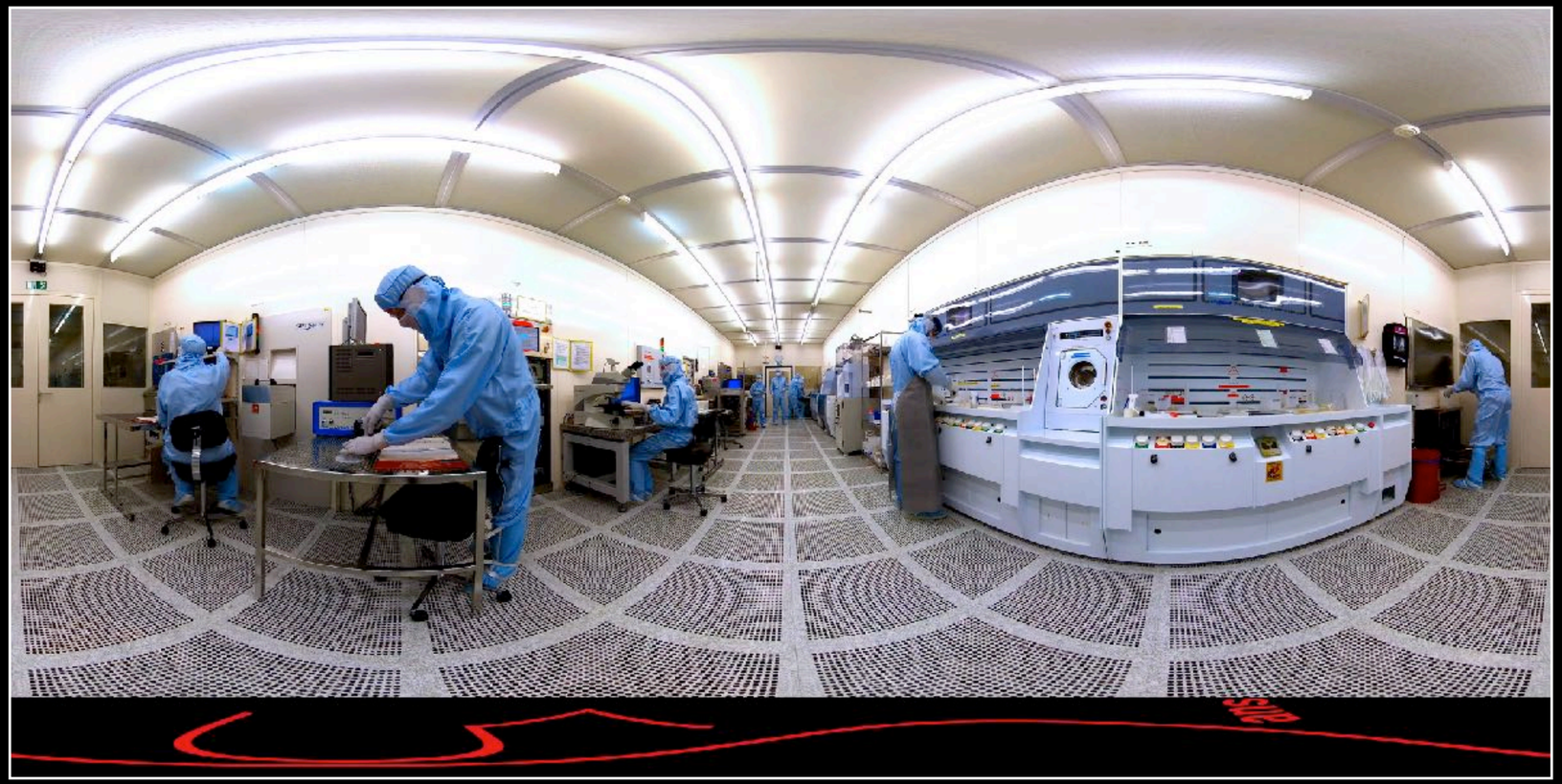

- To magnify something or to see more detail the camera needs to move closer towards it.

- Actually it is the notion of zoom in traditional film that is the strange case, our eyes cannot zoom in real life. So when one creates displays that are closer to the way we see the real world, we lose some of the artificial devices … like zooming.

# Miscellaneous topics - Wrapping

- Equirectangular images wrap horizontally so pixels to the right of the right edge are actually on the left edge.
- Need to be careful with imaging effects that affect neighbouring pixels. For example, colour changes generally don’t, but operations like sharpening do.
- Compositing also needs to occur across the wrapping zone.
- Note also the expansion at the poles. Editing software needs to be equirectangular aware.

# Miscellaneous topics - Nonlinear space




50 ans

# Miscellaneous topics - dynamic range

- Colour fidelity, depth and dynamic range more important than for standard limited field of view video.
- One is capturing everything, if outside during the day then the sun is always in shot.
- Increasingly once cameras get above 8K the more important metric is bit depth.

# Miscellaneous topics - Hiding

- There is no place for the traditional shoot for boom mics, lighting, choreographer, director, etc.

# Stereoscopic (VR)

- Stereoscopic filming is a whole topic in itself and should start with a good understanding of stereoscopic theory for flat screens first.
- Obviously head mounted (VR) displays are geared to support this.
- Well understood for computer generated content (still not always done well!).
- Hugely problematic for video recording despite lots of camera rigs (including the Insta360Pro-2) supporting it.
- Quality is generally not of a high standard and is only accepted due to novelty and low user expectations.
- Happy to take questions on this now or later.

End - Questions?