360 video

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http://paulbourke.net/ECU2020/

Agenda

History - Examples from authors projects

Why?

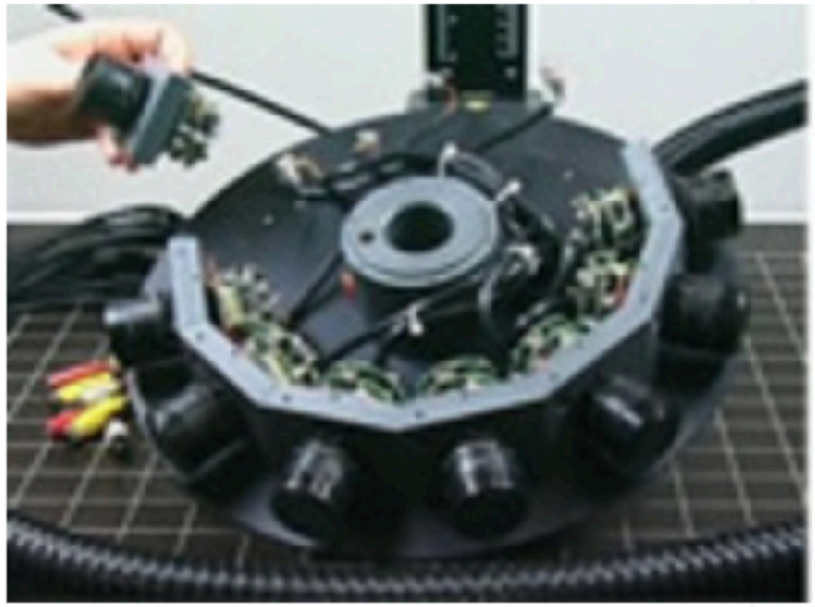
Image projections
(Perspective - Fisheye - Cylindrical panorama - Cube maps - Equirectanglar panorama)

Camera summary
(One - Two - More than two)

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

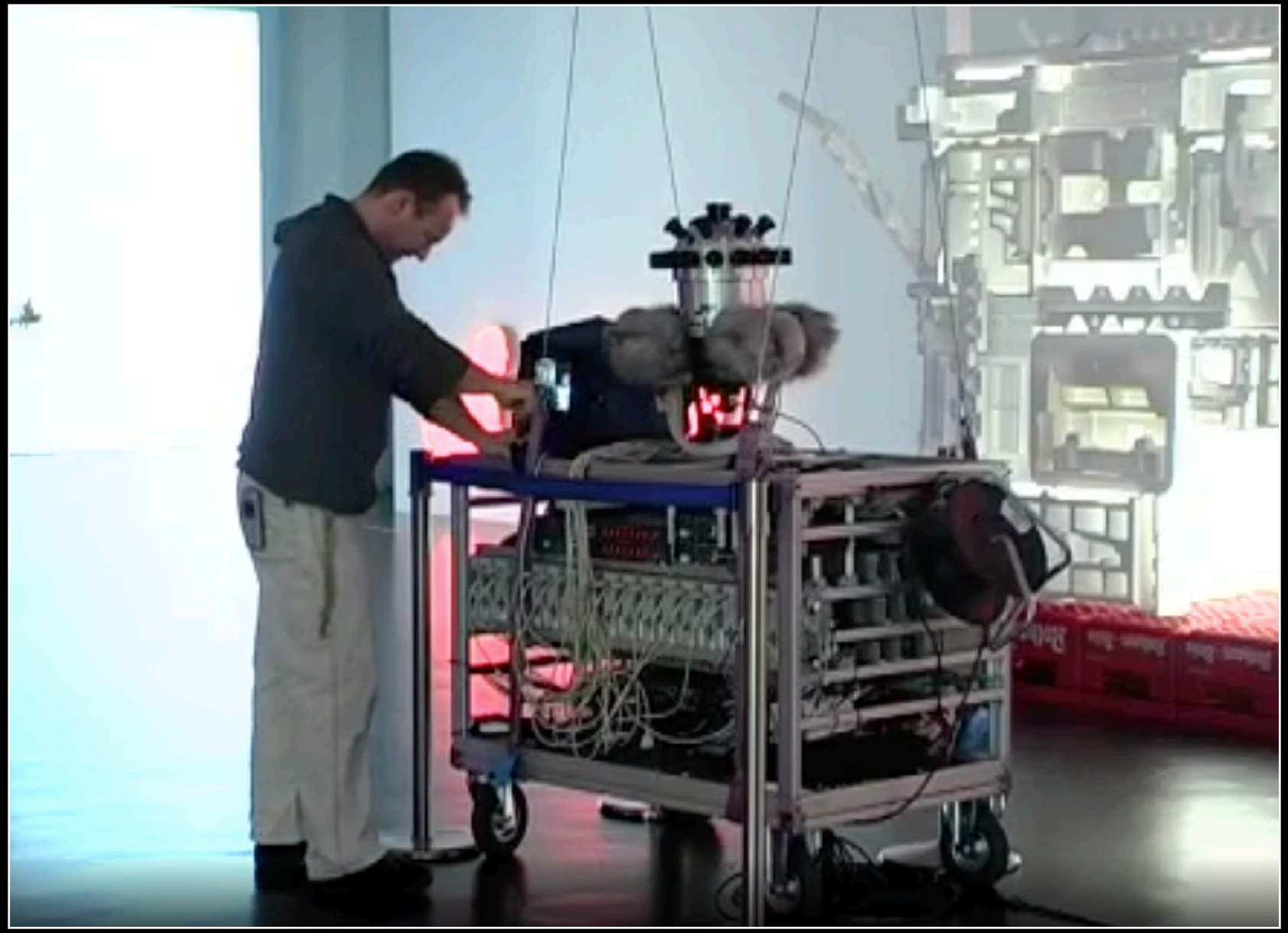
Miscellaneous topics
(Conventions, problems, differences, tricks ….)

History



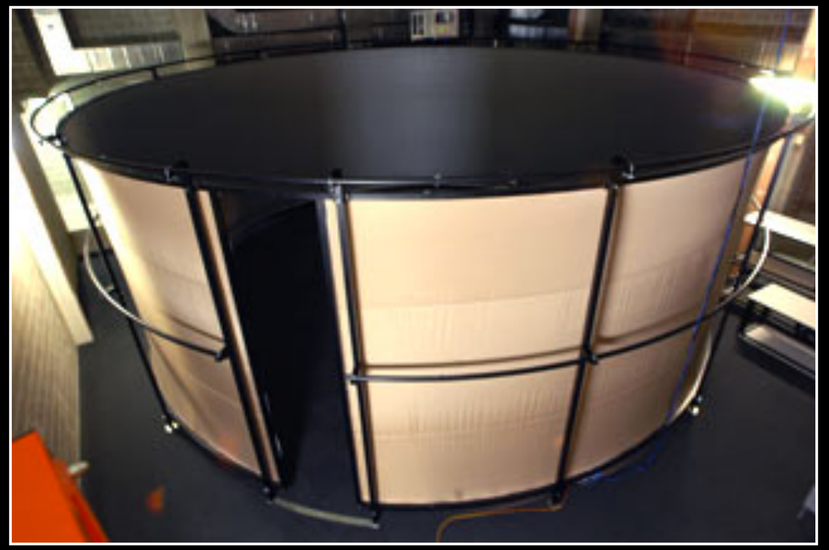
Jeffrey Shaw, ZKM

Spherecam



Examples - 2002

iCinema



Ladybug range of cameras: 2,3,5,5+

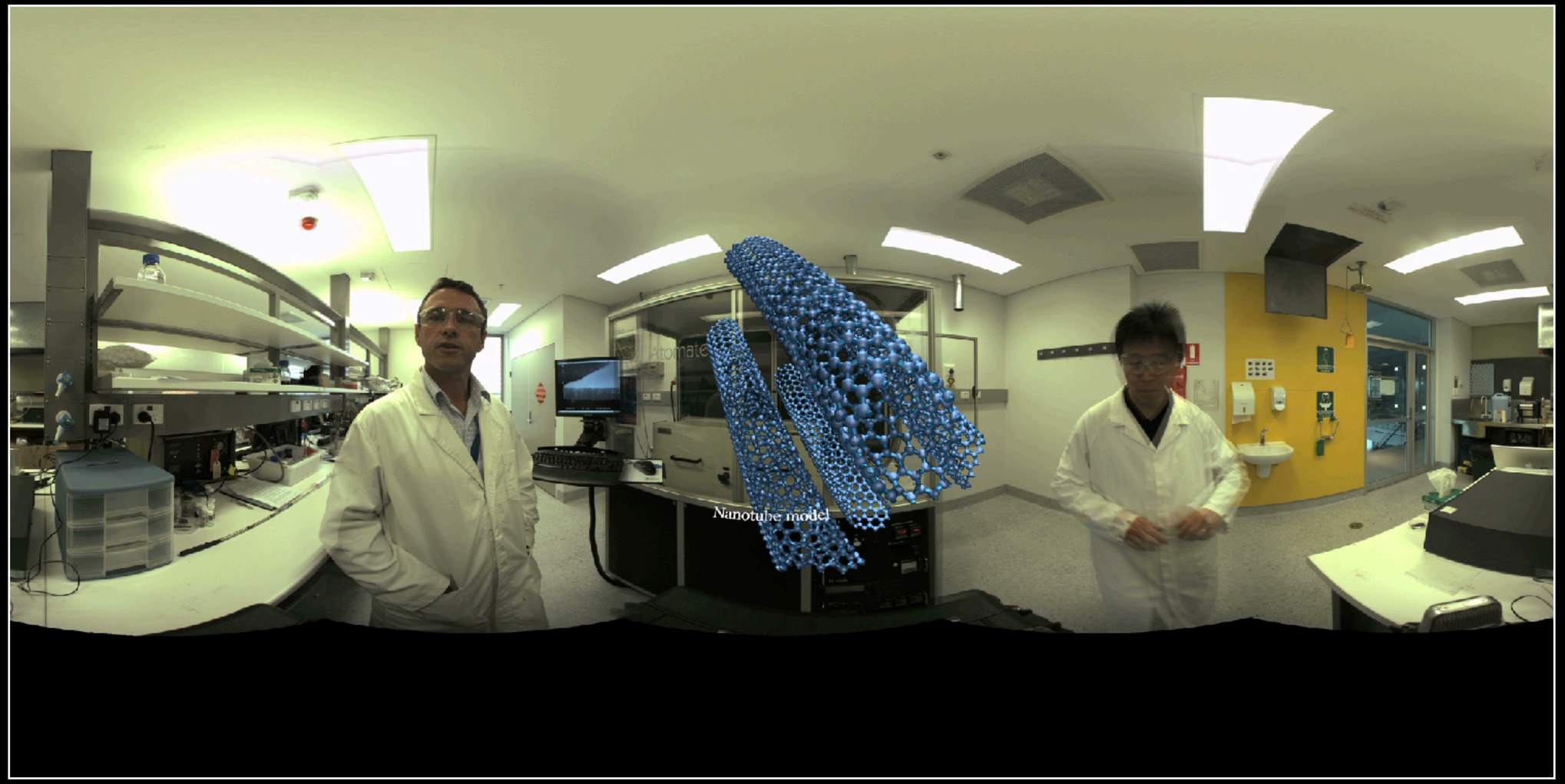
Fiming cultural events in Turkey

Examples - 2010

Hashibektashi, Turkiye

Whirling Dervish, Turkiye

Karratha iron ore ship loader



Nanotechnology, Wollongong

Sheep shearing, Barossa valley

Examples - 2015

Pig farming in Hong Kong

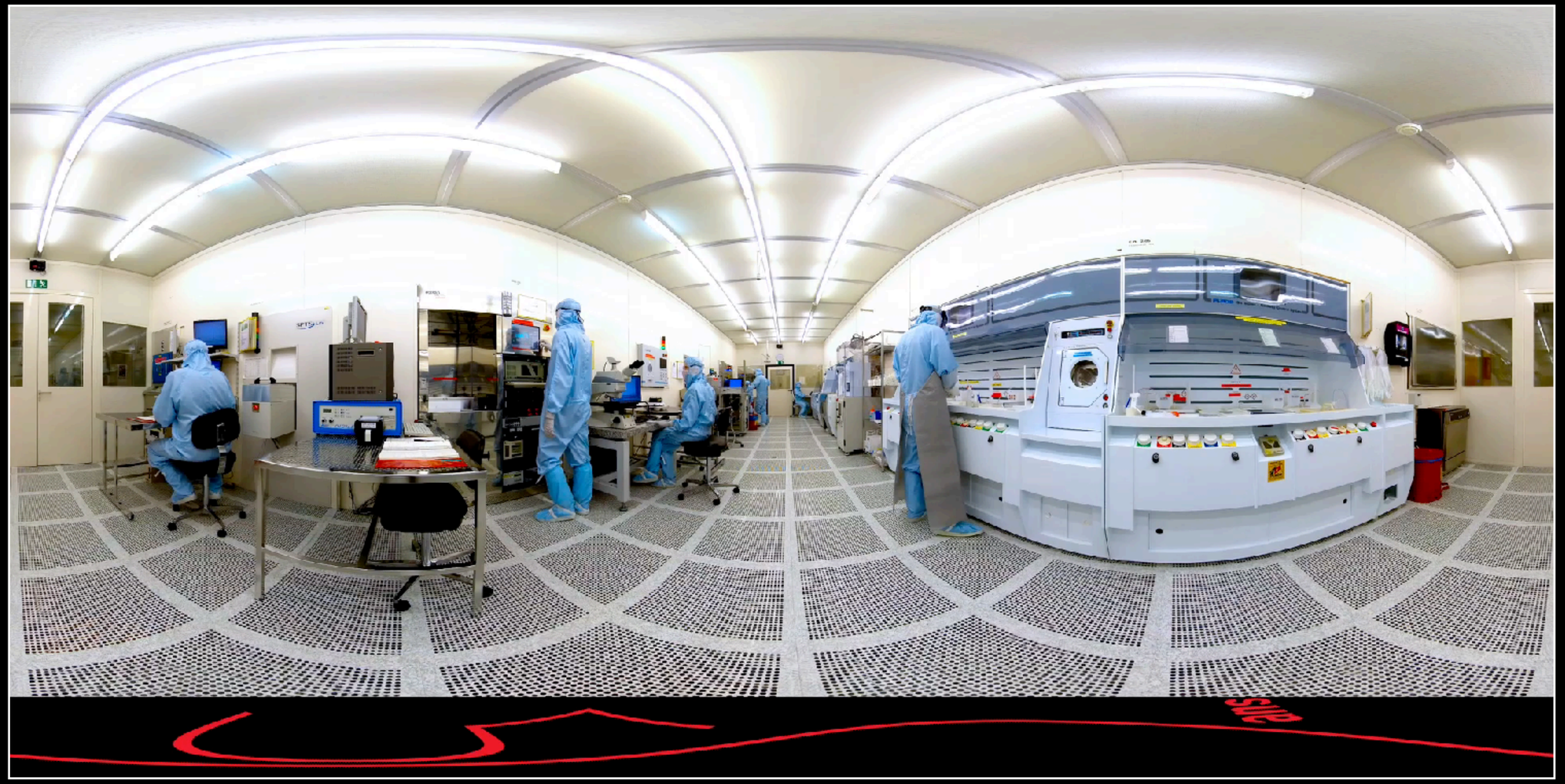
Obsidian camera

Examples - 2018

Sahet-Jetavana, India

Insta360Pro

Clothing Buddha, India

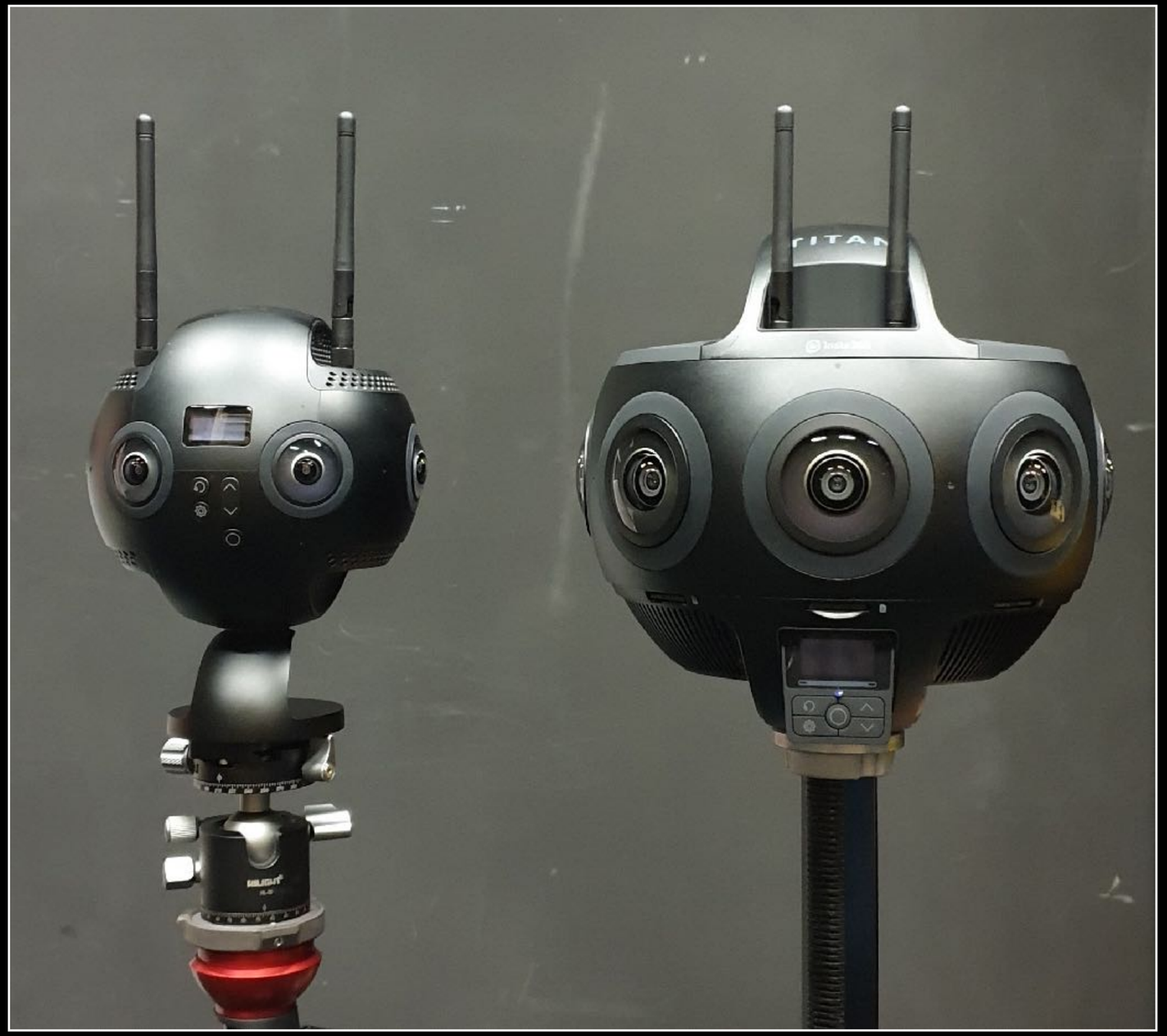


Micro and Nano Technology, EPFL, Switzerland

Insta360Pro

Examples - 2020

Insta360 Pro2



Titan

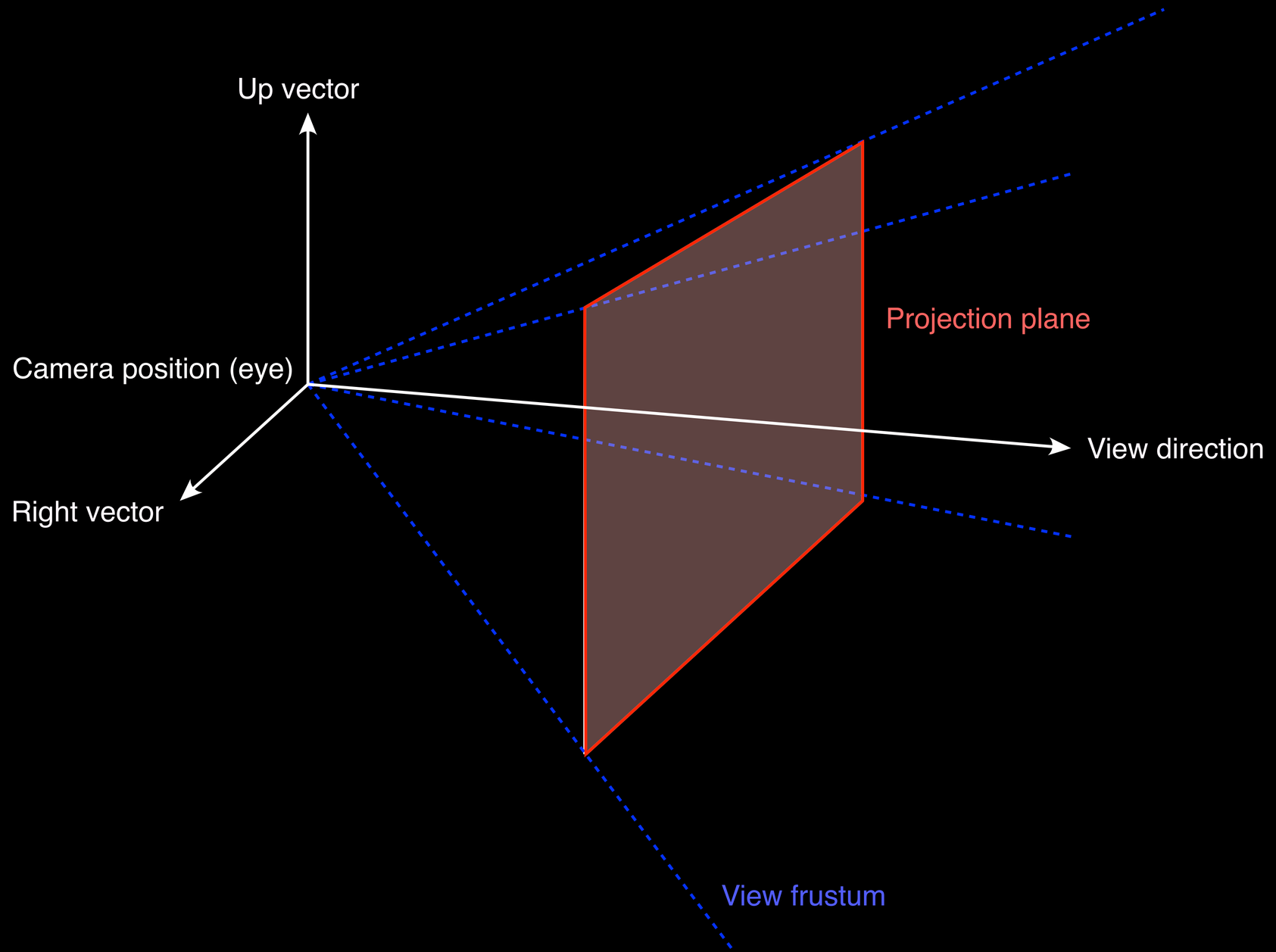
Shanghai temple, January 2020

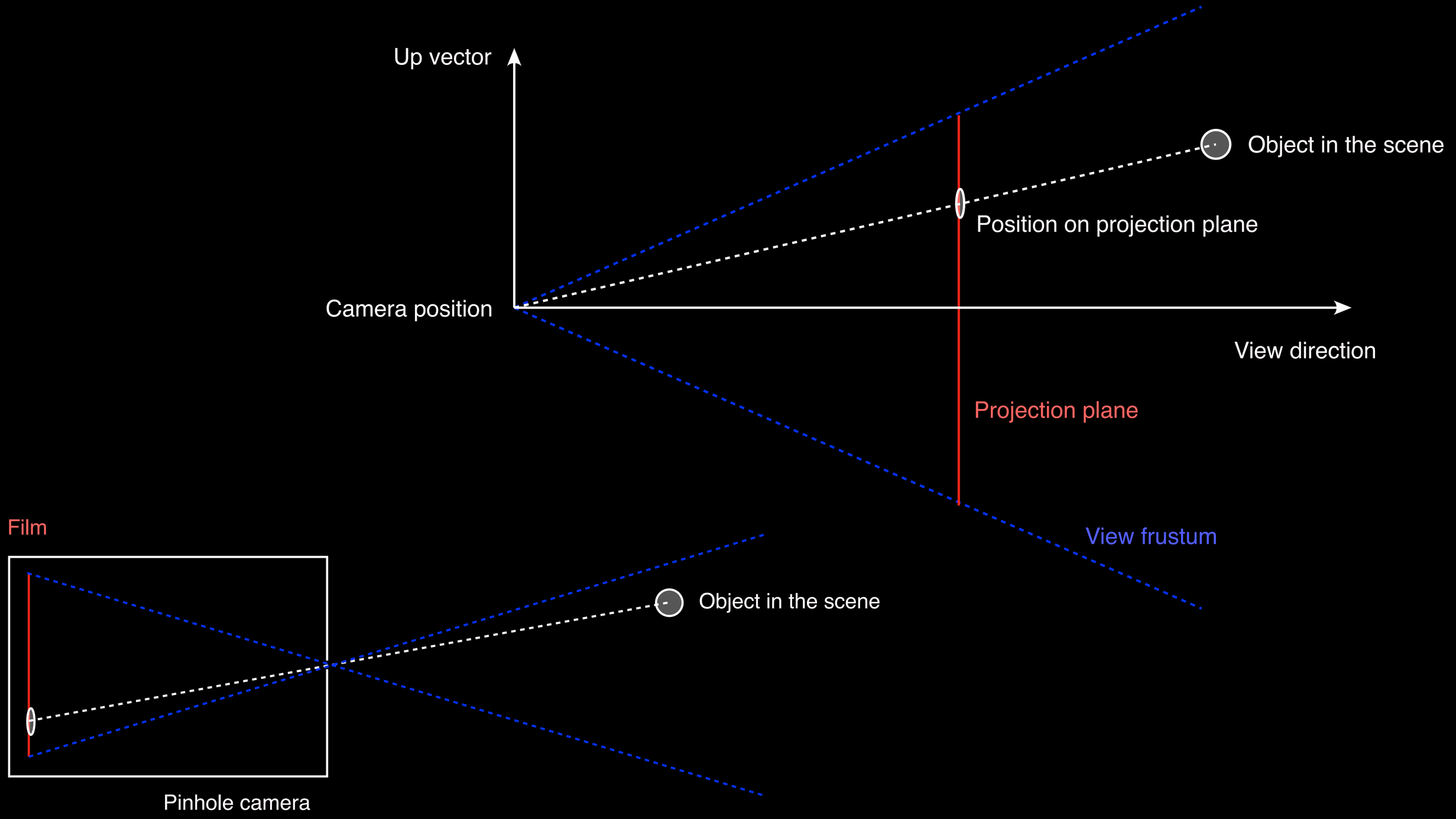
Chinese new year fireworks, Fo Guang Shan temple, Taiwan. January 2020

Why?

- Immersion.
- The sense of immersion here is the physical one, when our whole visual field of view is stimulated.
- The sense of “presence”, of “being there”.
- Head mounted displays are the most convincing examples.
- Not a new idea, the whole point of wide aspect movie theatres, omnimax dome theatres.
- Often referred to as “removing the frame”.

Image projections




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

Perspective projection

60 degree FOV

100 degree FOV

140 degree FOV

Fisheye projection

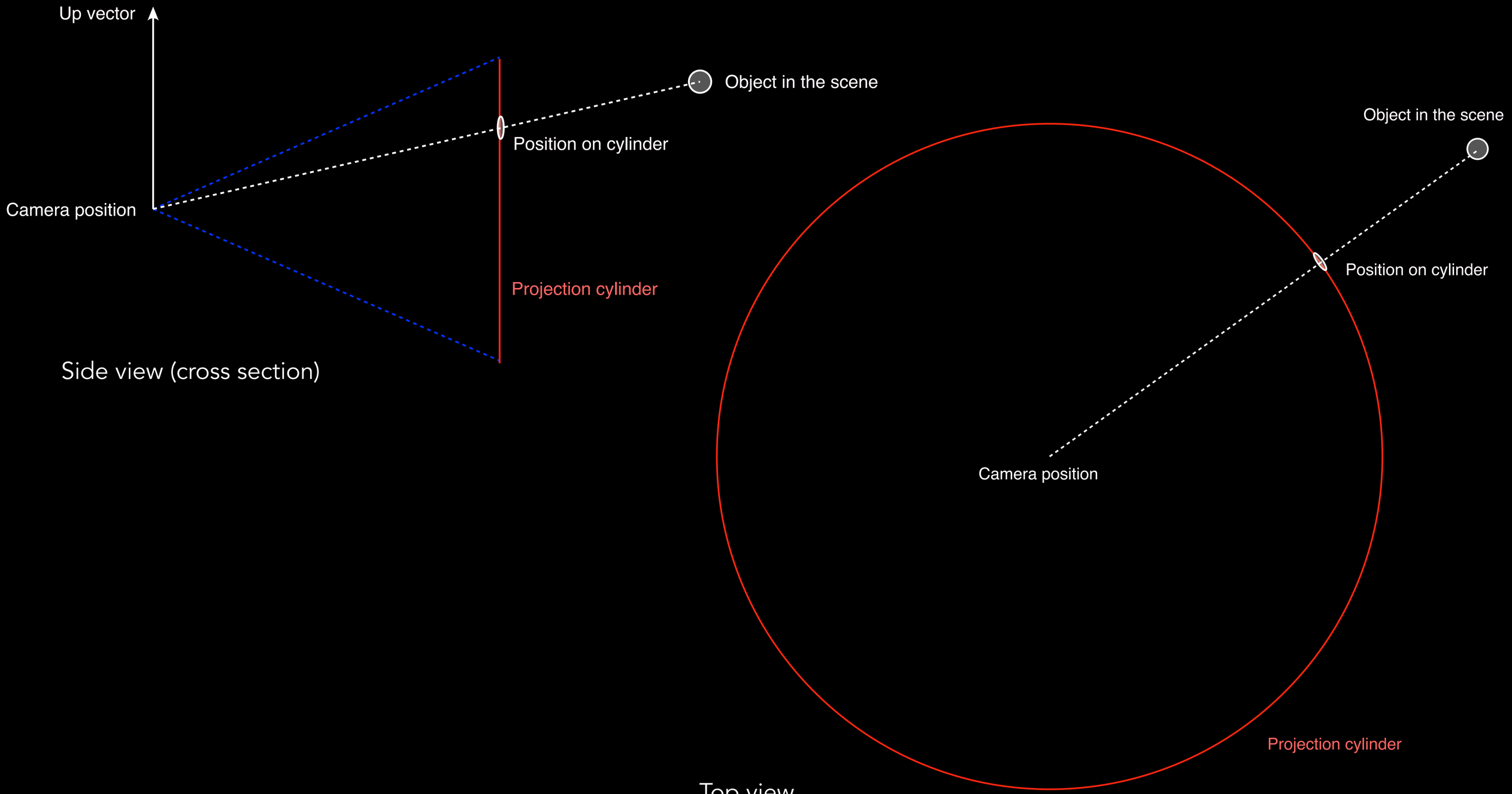
180 degree fisheye

180 degree fisheye

Cylindrical panorama

60 degrees vertical FOV

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

100 degrees vertical FOV

140 degrees vertical FOV

Cube maps

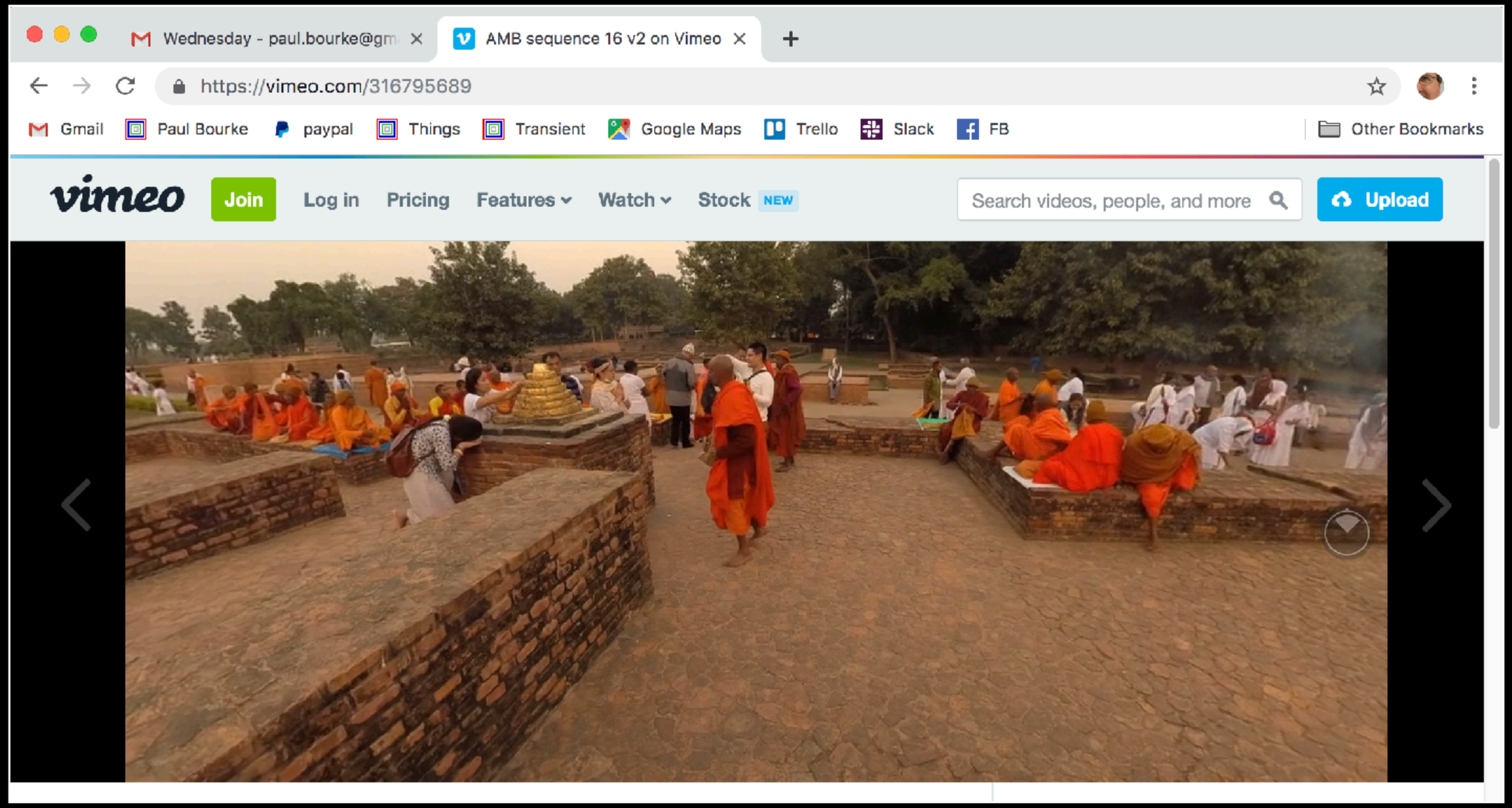
Equirectangular (sometimes simply “spherical”) projection

180 degrees

360 degrees

Viewing environments

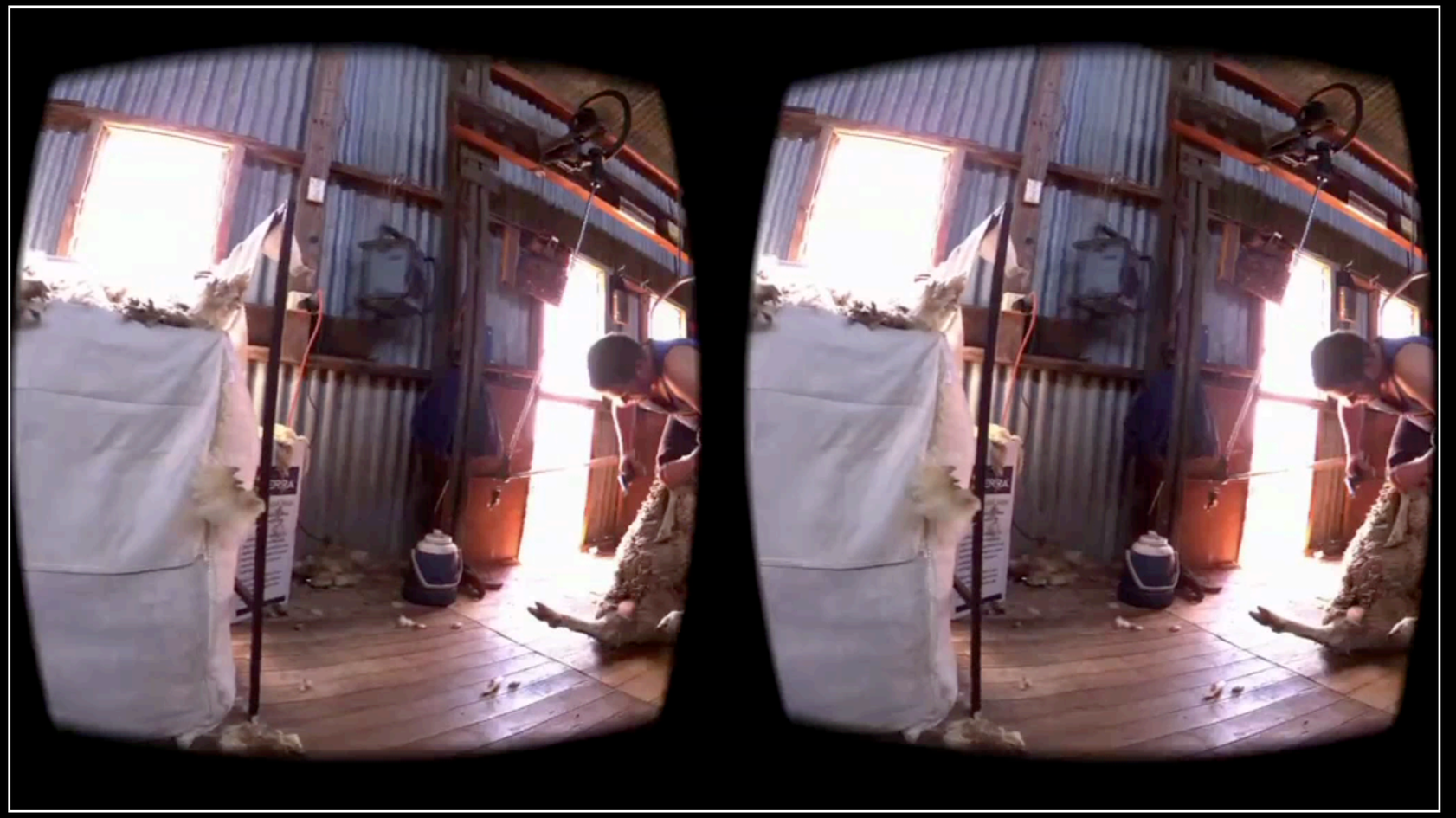
Perspective

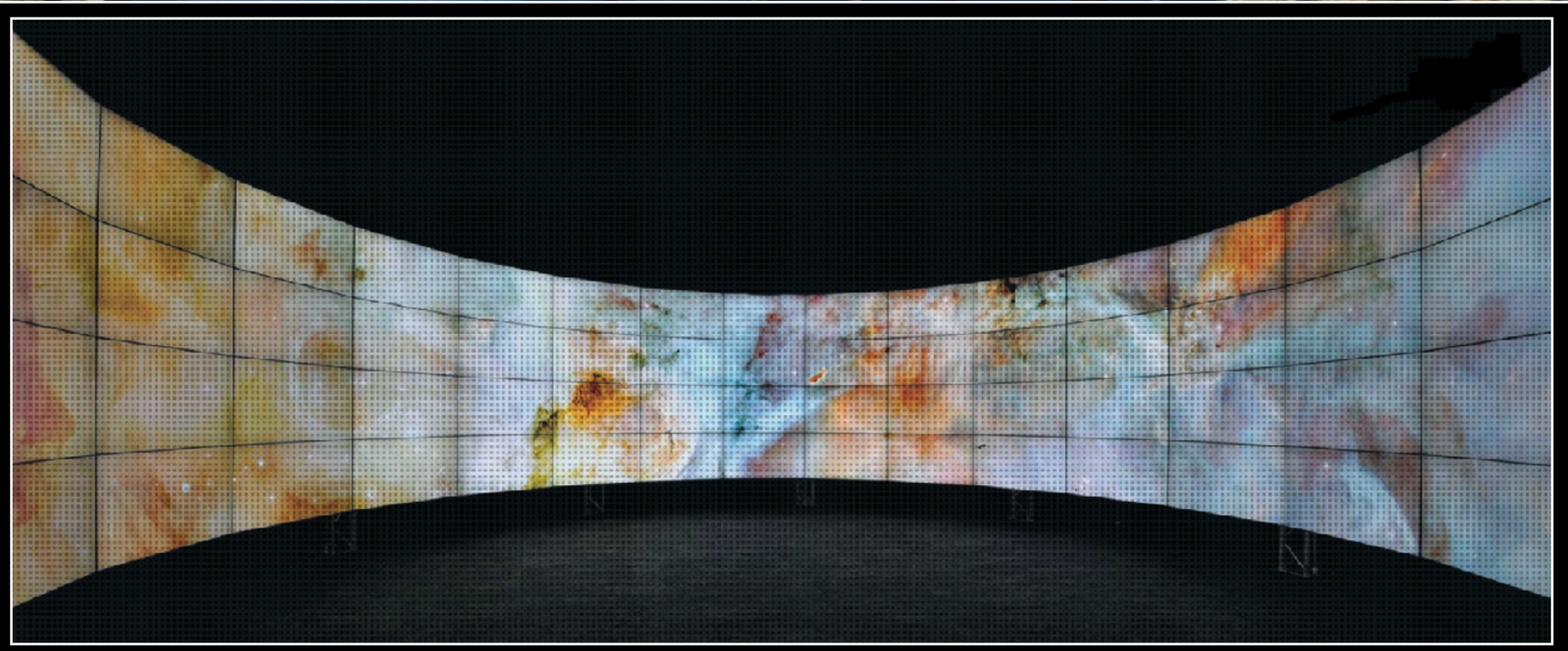


https://vimeo.com/316795689

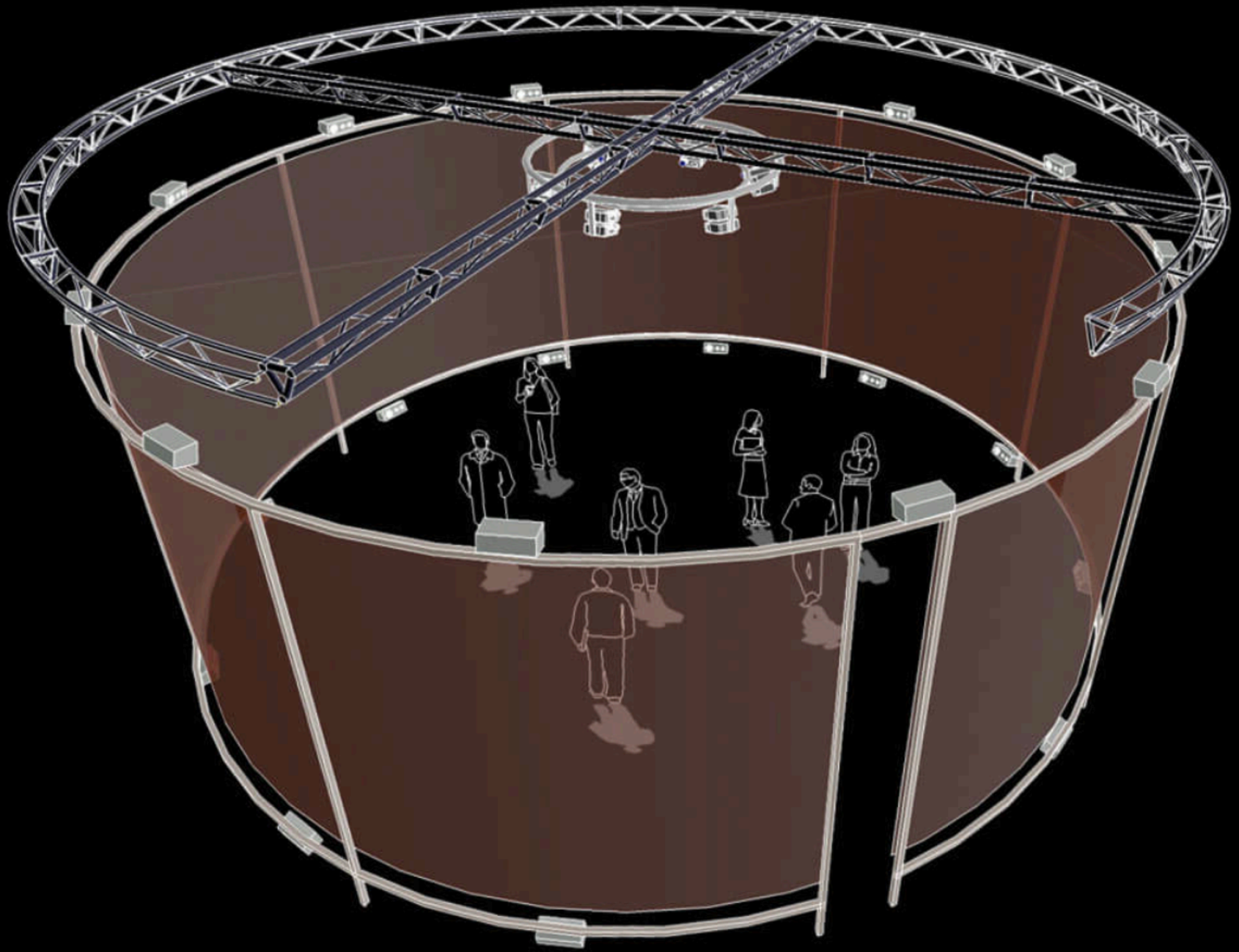

Oculus


VIVE
VIVE





University of the Sunshine Coast

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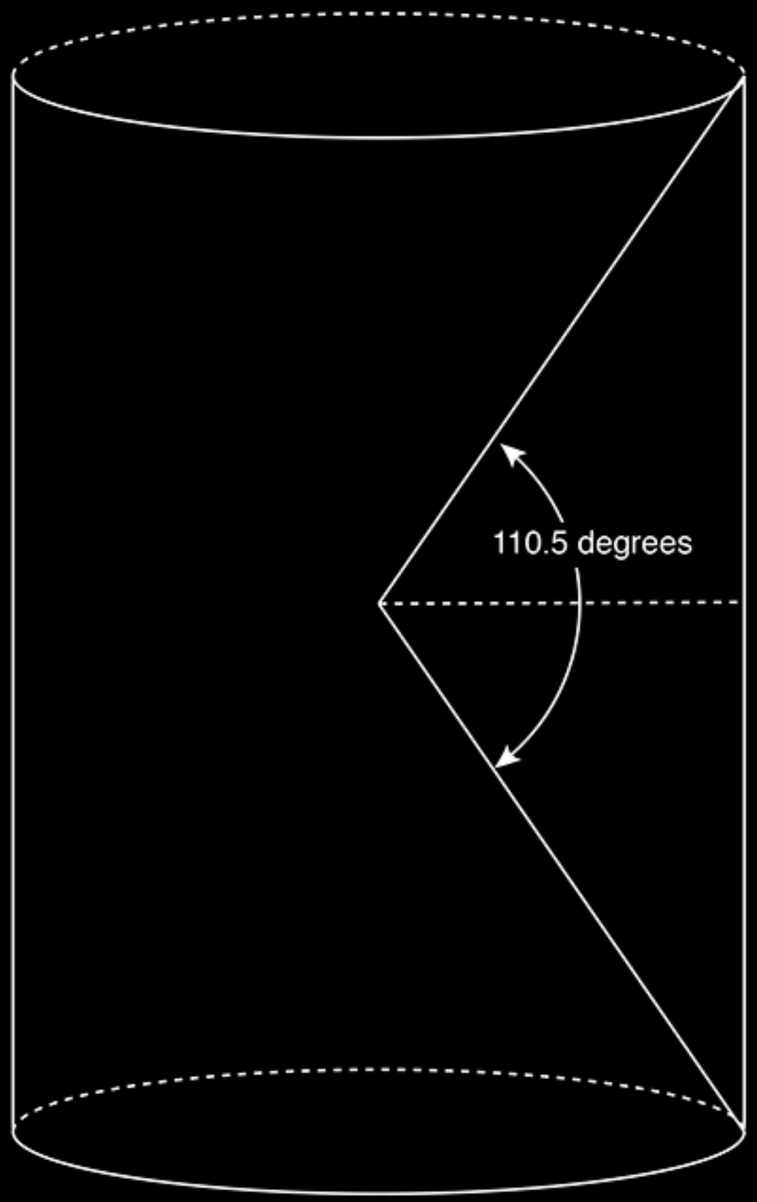

110.5 degrees


coles

Fisheye


Fit for Life
TREADMILLS

Broad camera classifications

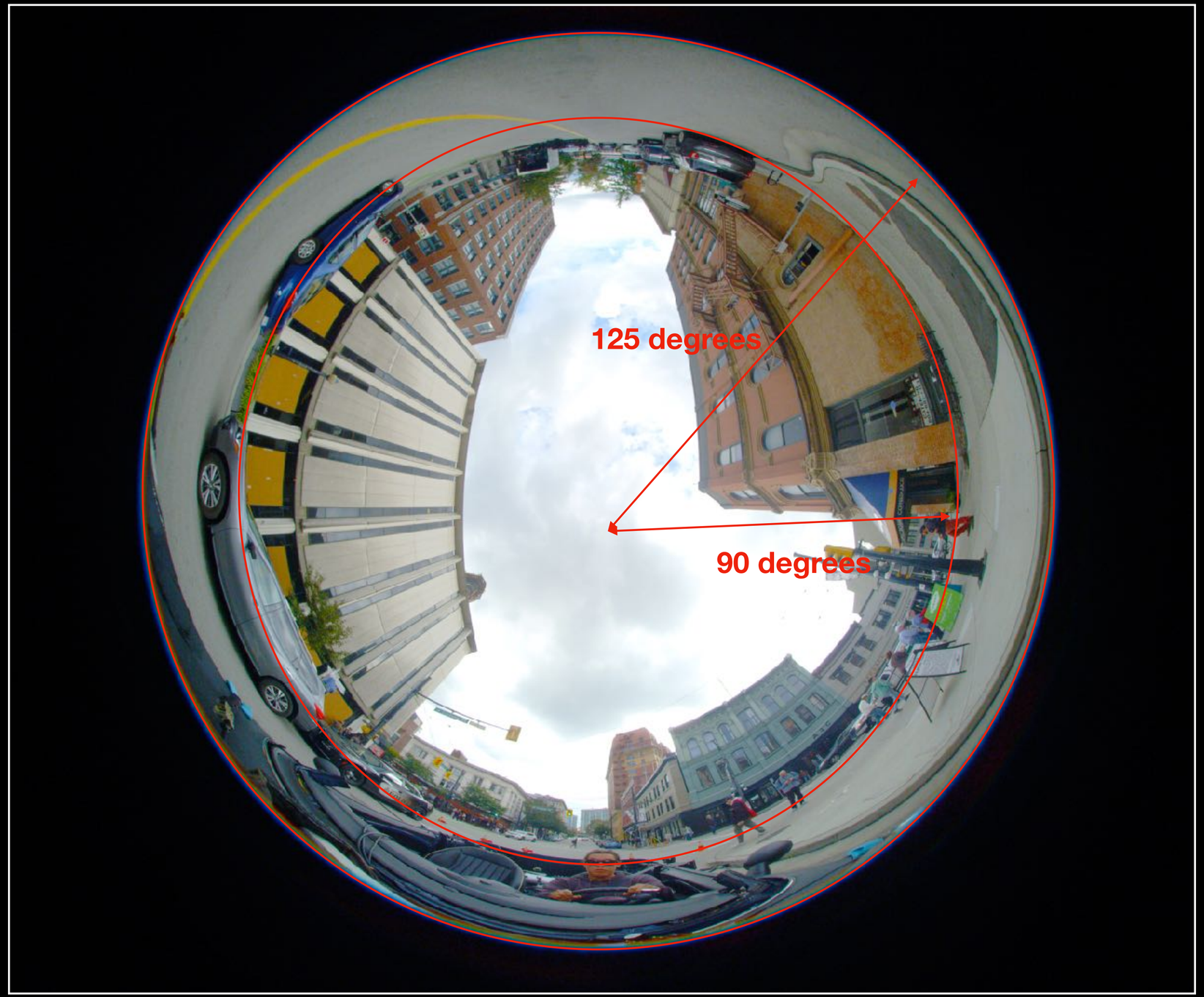
Single camera + wide angle fisheye lens

Dual camera rigs

Greater than 2 camera rigs, typically 5 or more

Single camera + fisheye lens

Entaniya 250 degree fisheye


125 degrees
90 degrees


90 degrees
35 degrees

Single camera merits

Advantages:

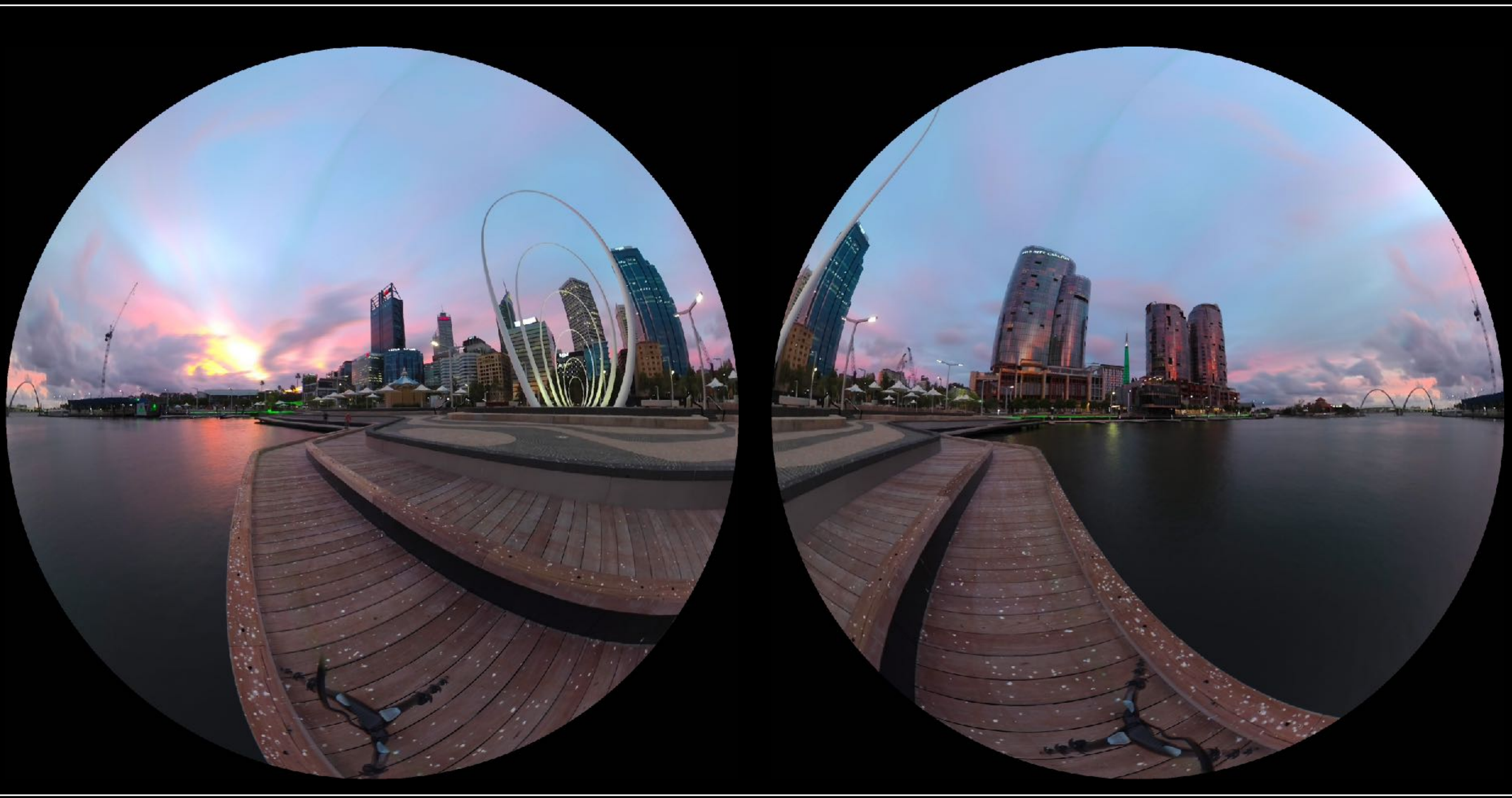
Simple - Small - No blending - No parallax errors

Disadvantages:

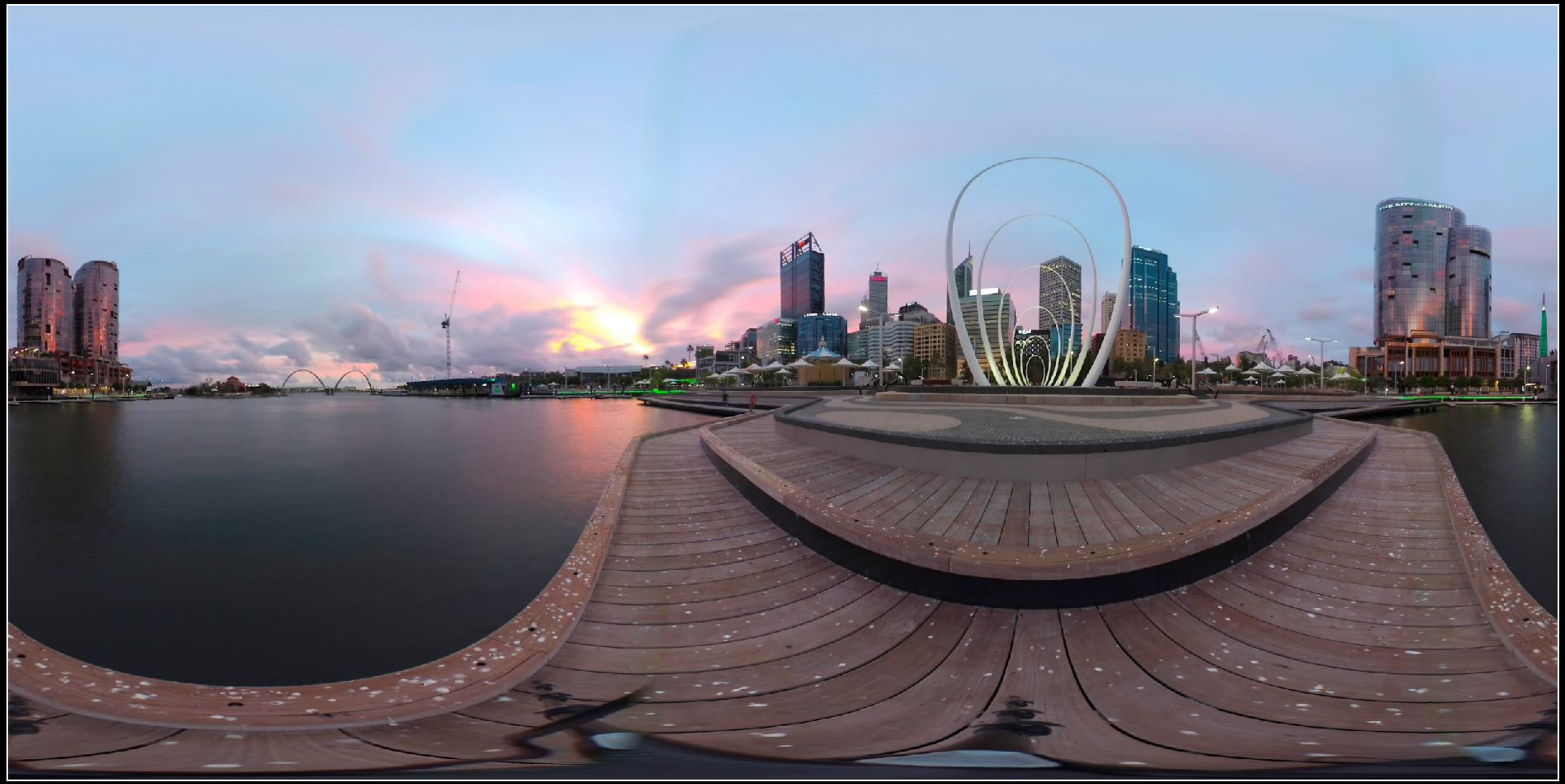
Doesn’t capture whole 360x180 field of view

Doesn’t scale!

Dual camera rigs



220 degree fisheye


THE RITZ-CARLTON

Dual camera merits

Advantages:

Small - Single blend line - Higher resolution than single camera

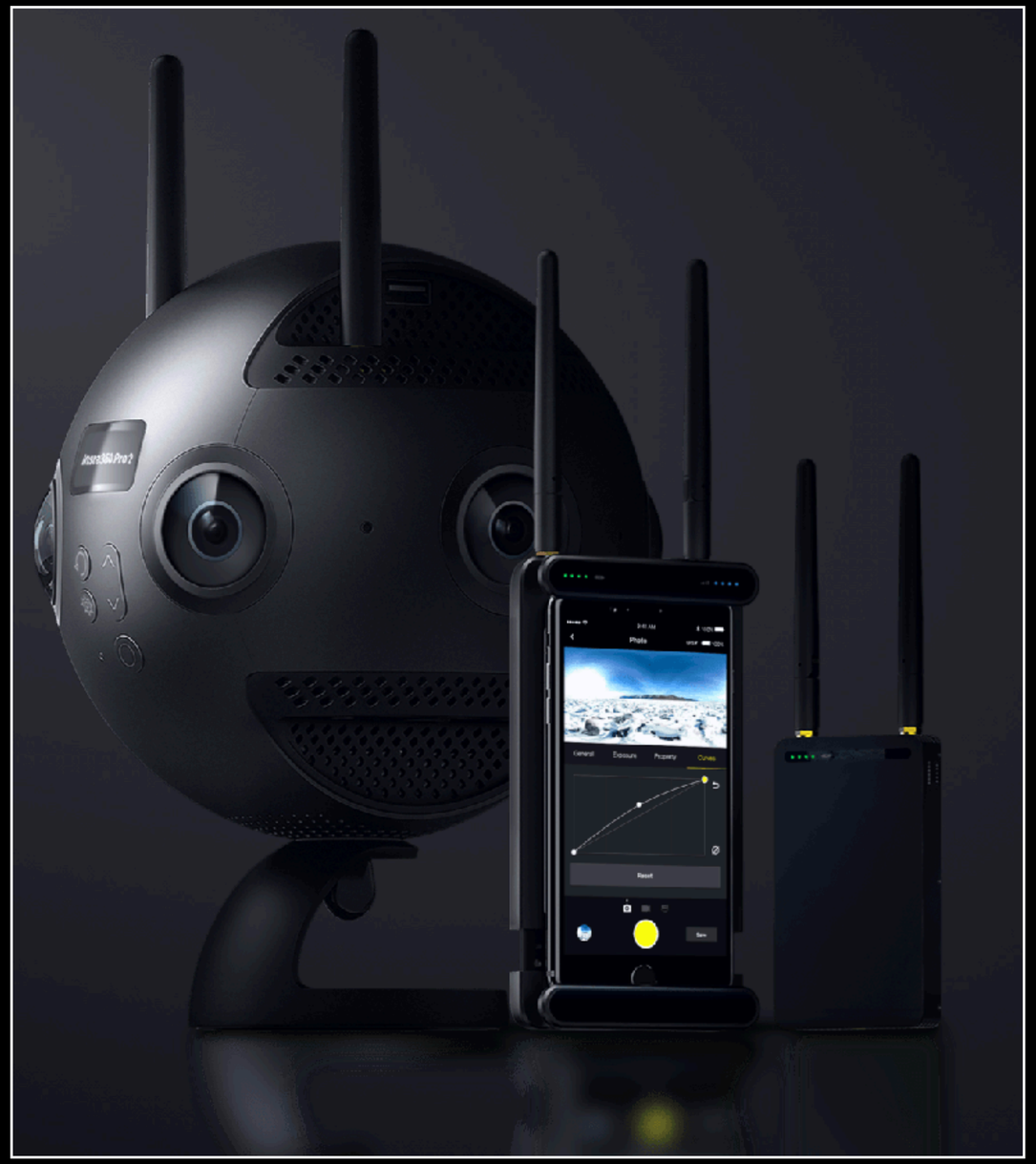
Disadvantages:

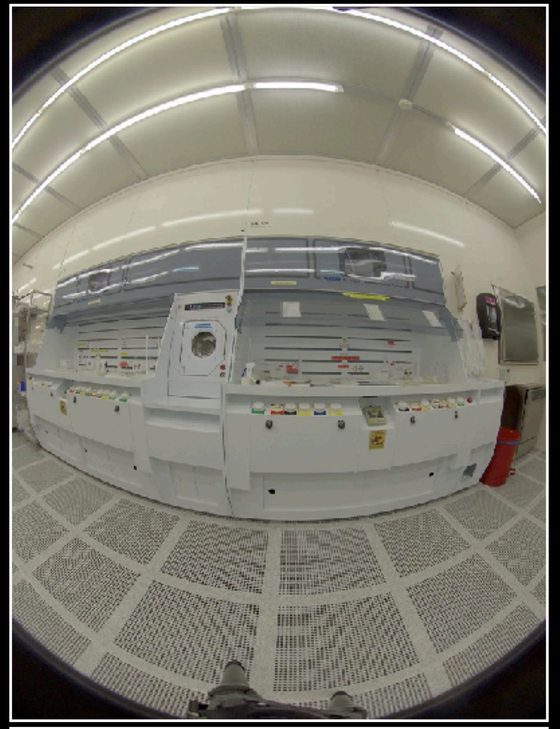
Doesn’t scale!

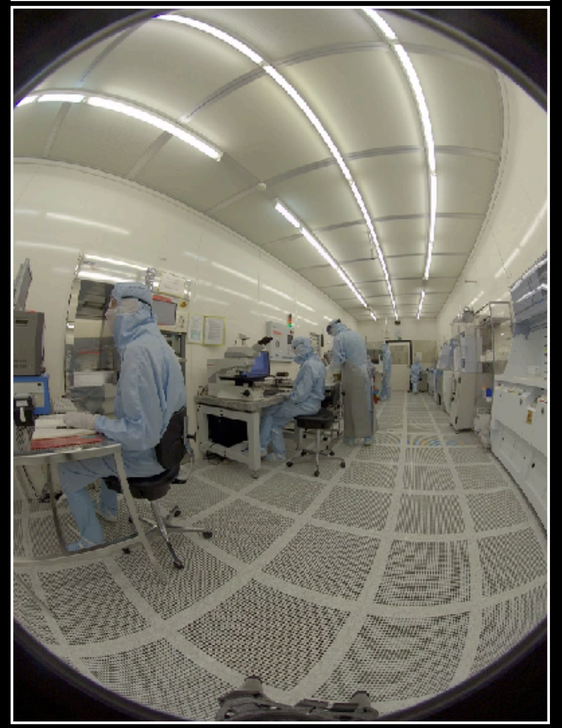
Cannot support stereoscopic 3D

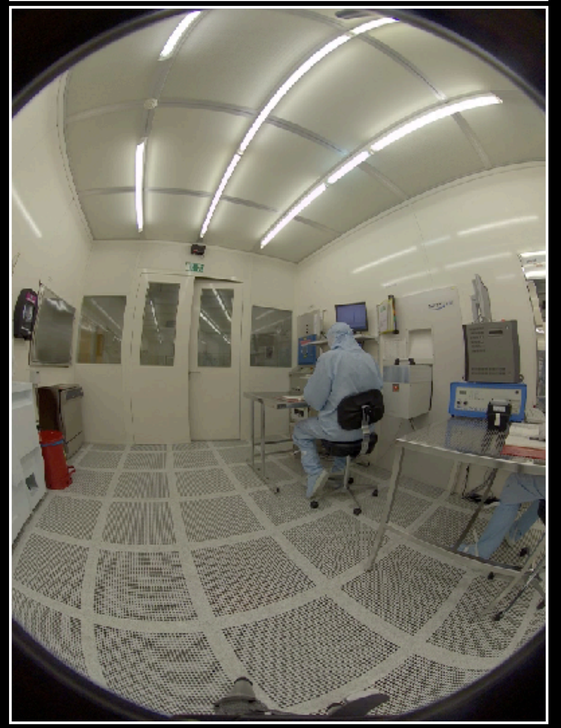
Multiple cameras (>2)

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







Multiple camera merits

Advantages:

Scales to higher resolution

Supports stereoscopic 3D

Disadvantages:

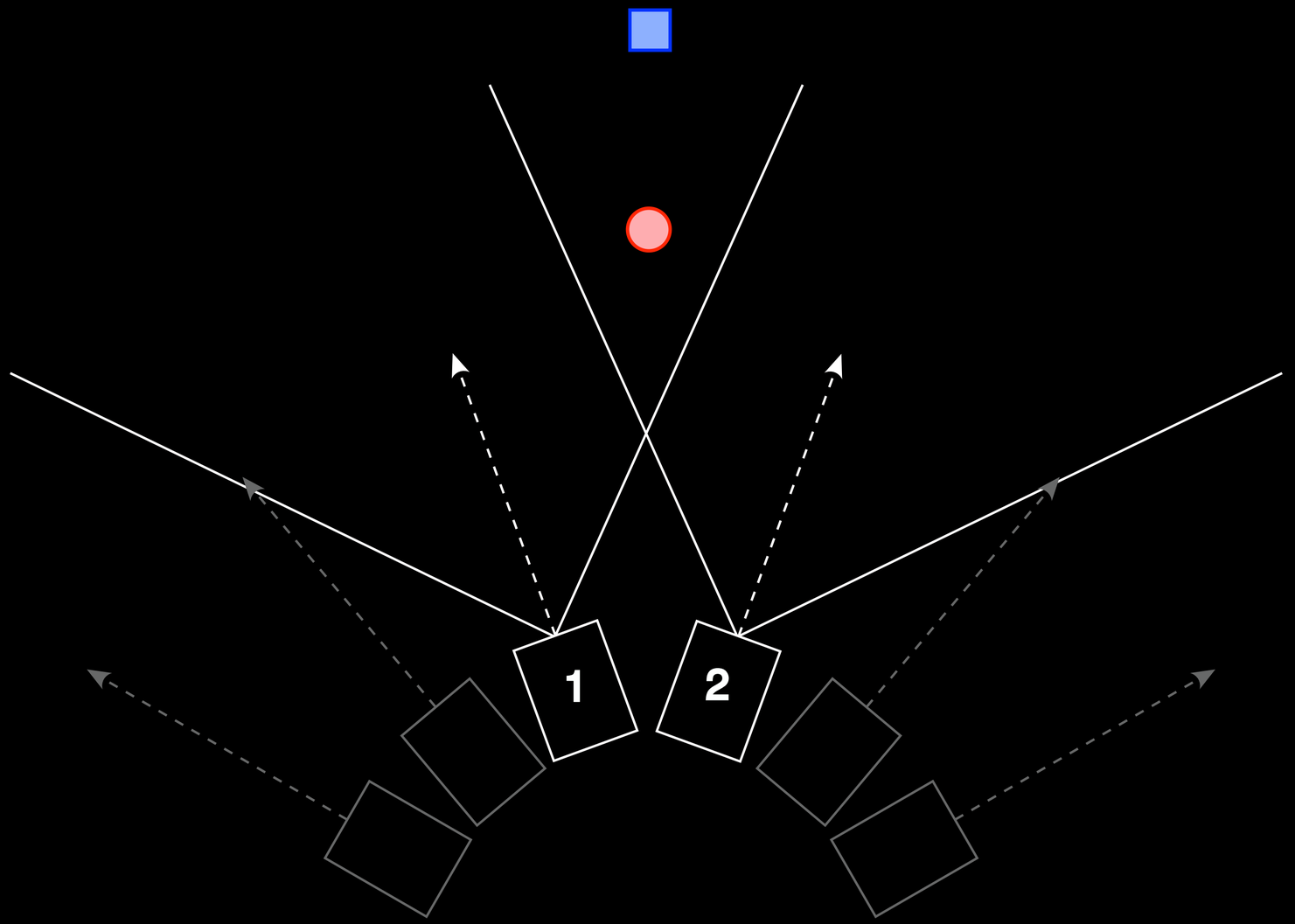
Larger units, More expensive

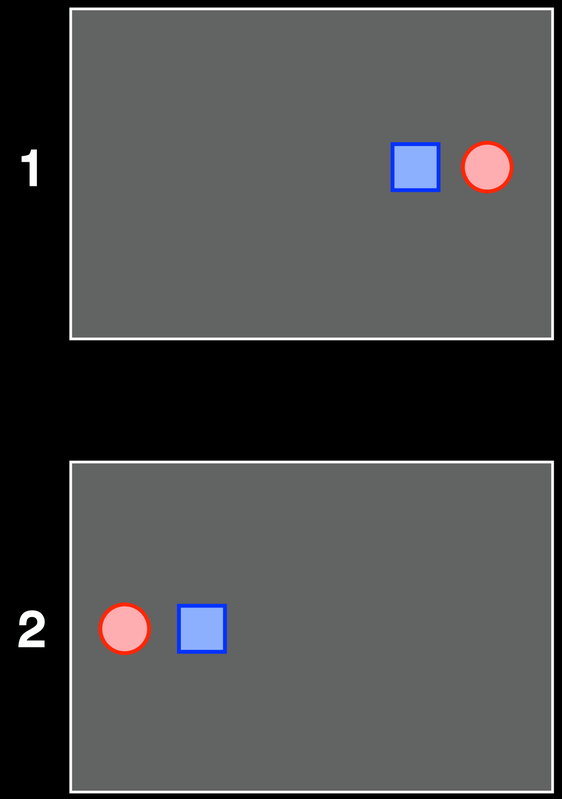
More complex data management and stitching

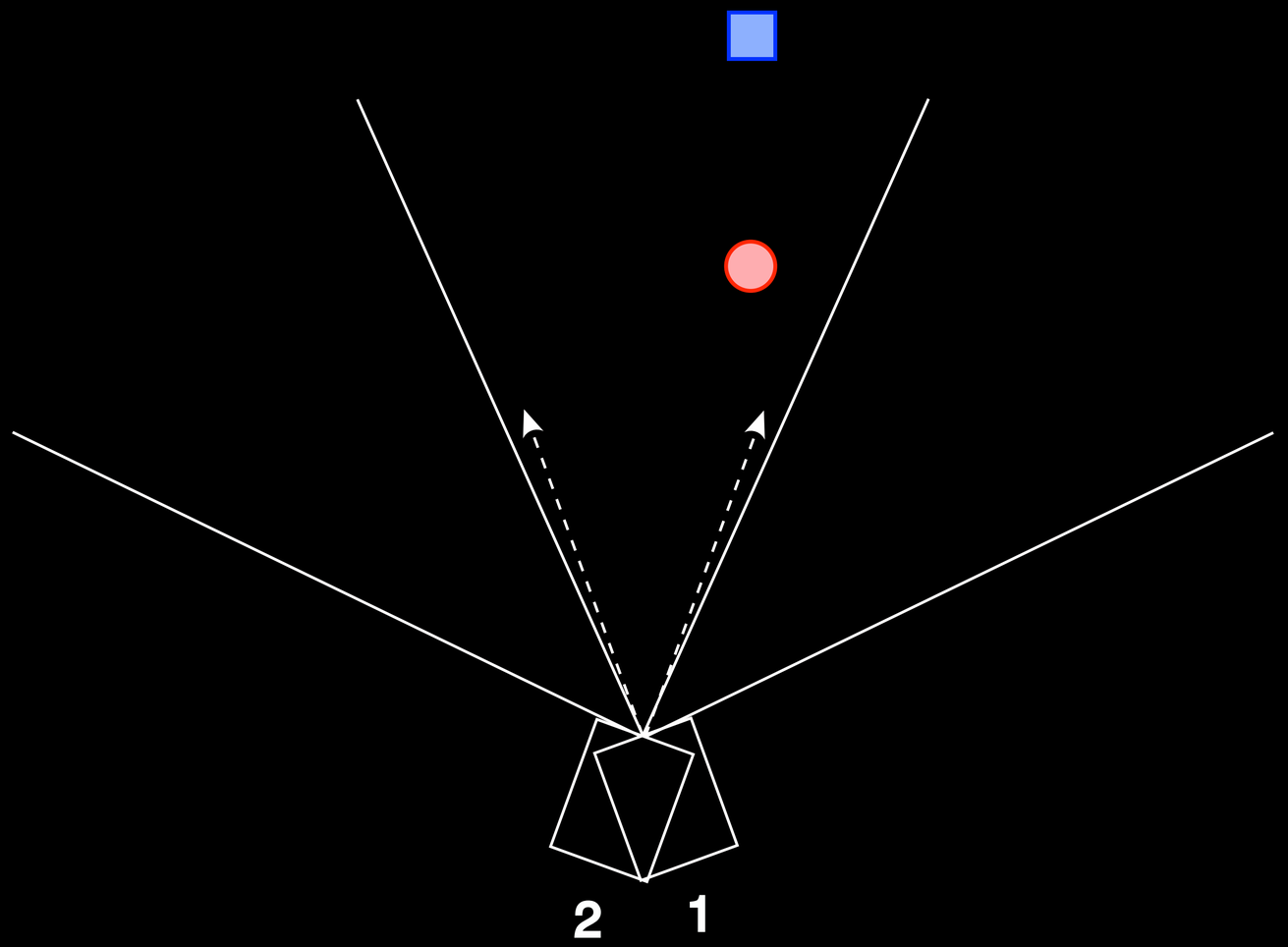
Summary

	Single camera	Dual camera	More than 2 cameras
Resolution	Rarely > 4K	5K -> 8K	8K or more
Stitching	None	Single strip	Multiple
Lens quality	Good	Generally poorer	Good
Size/weight/Price	Medium	Small	High
Full equirectangular	No	Usually	Usually
Stereoscopic 3D	No	No	Possible

The fundamental problem



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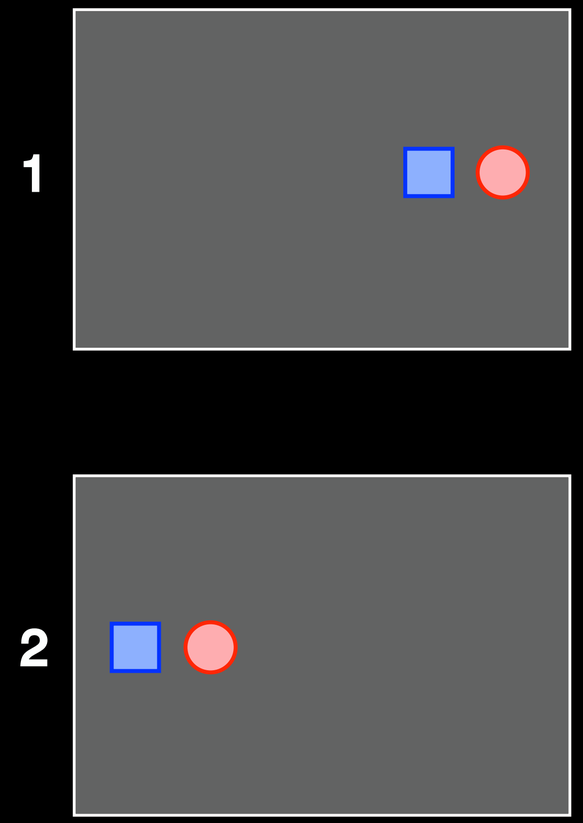
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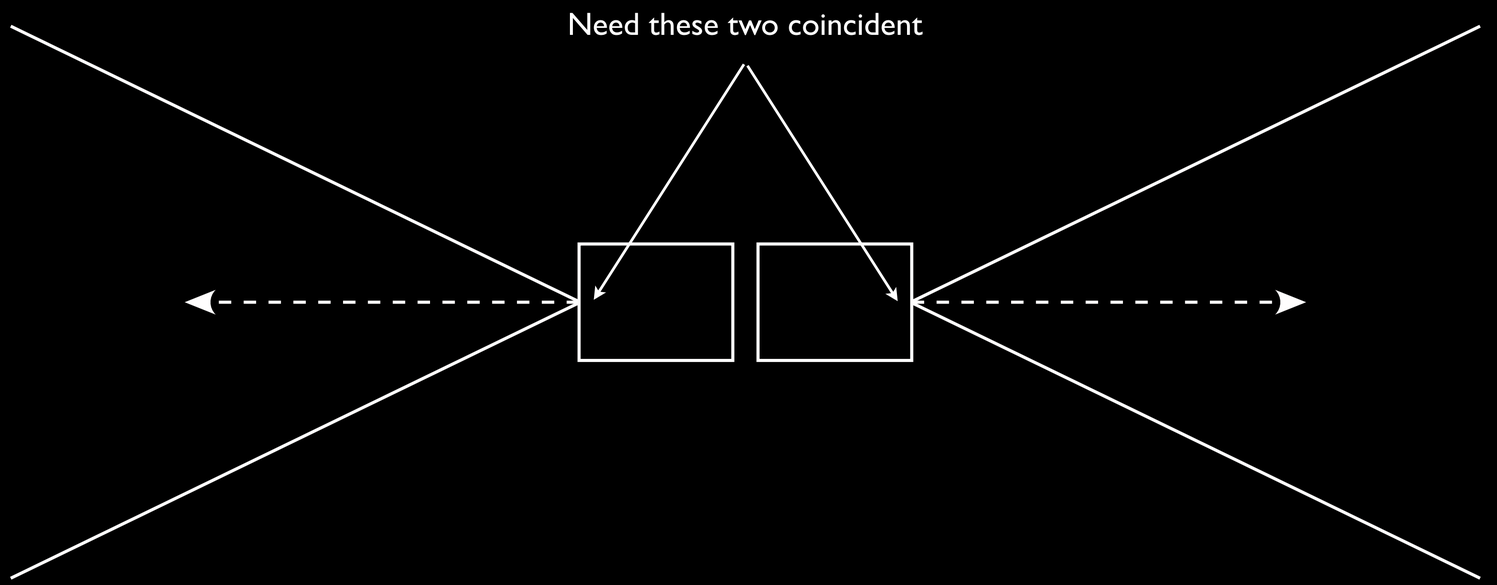
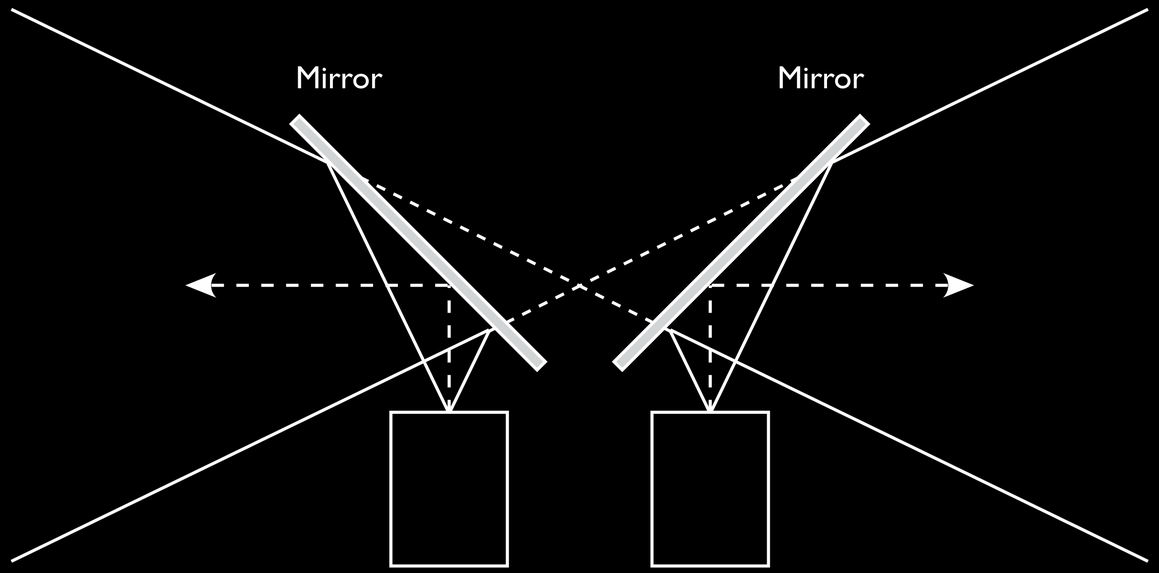
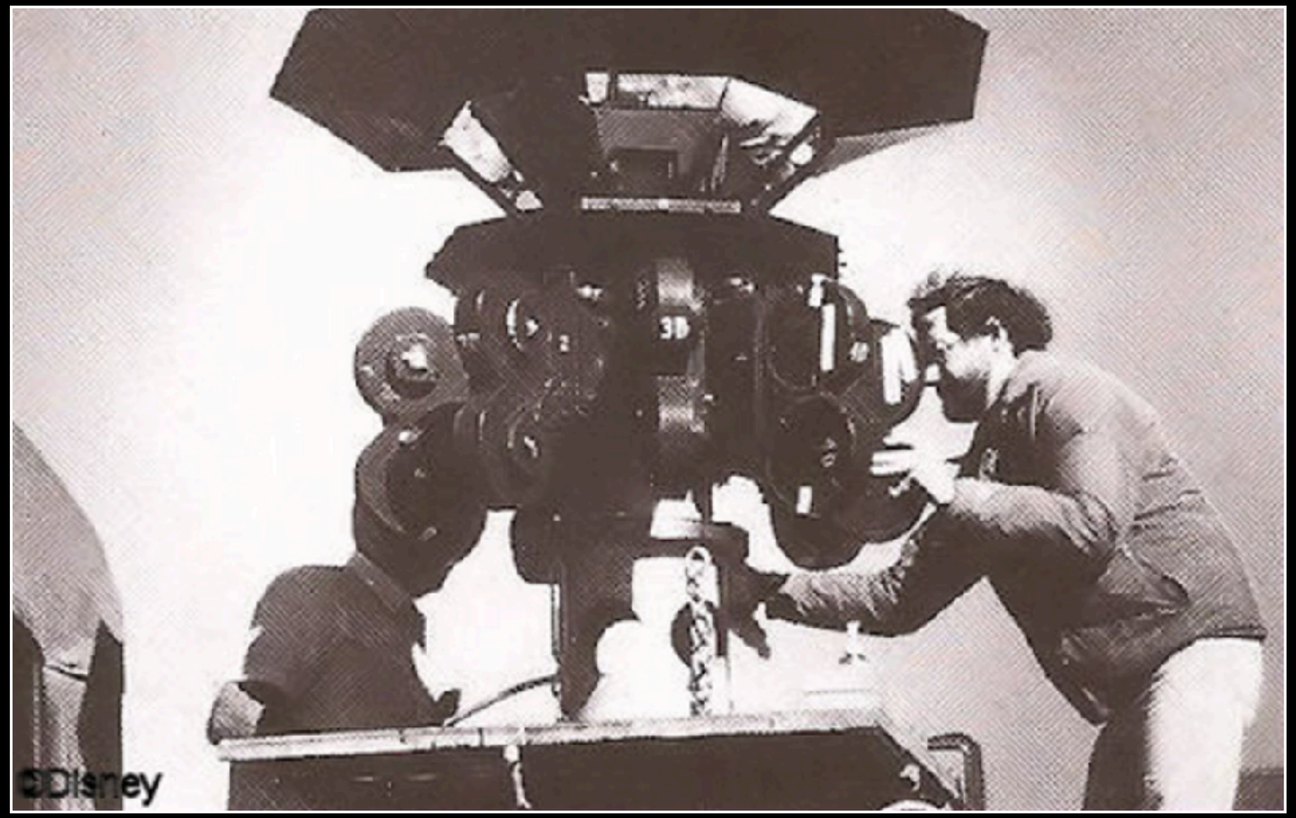
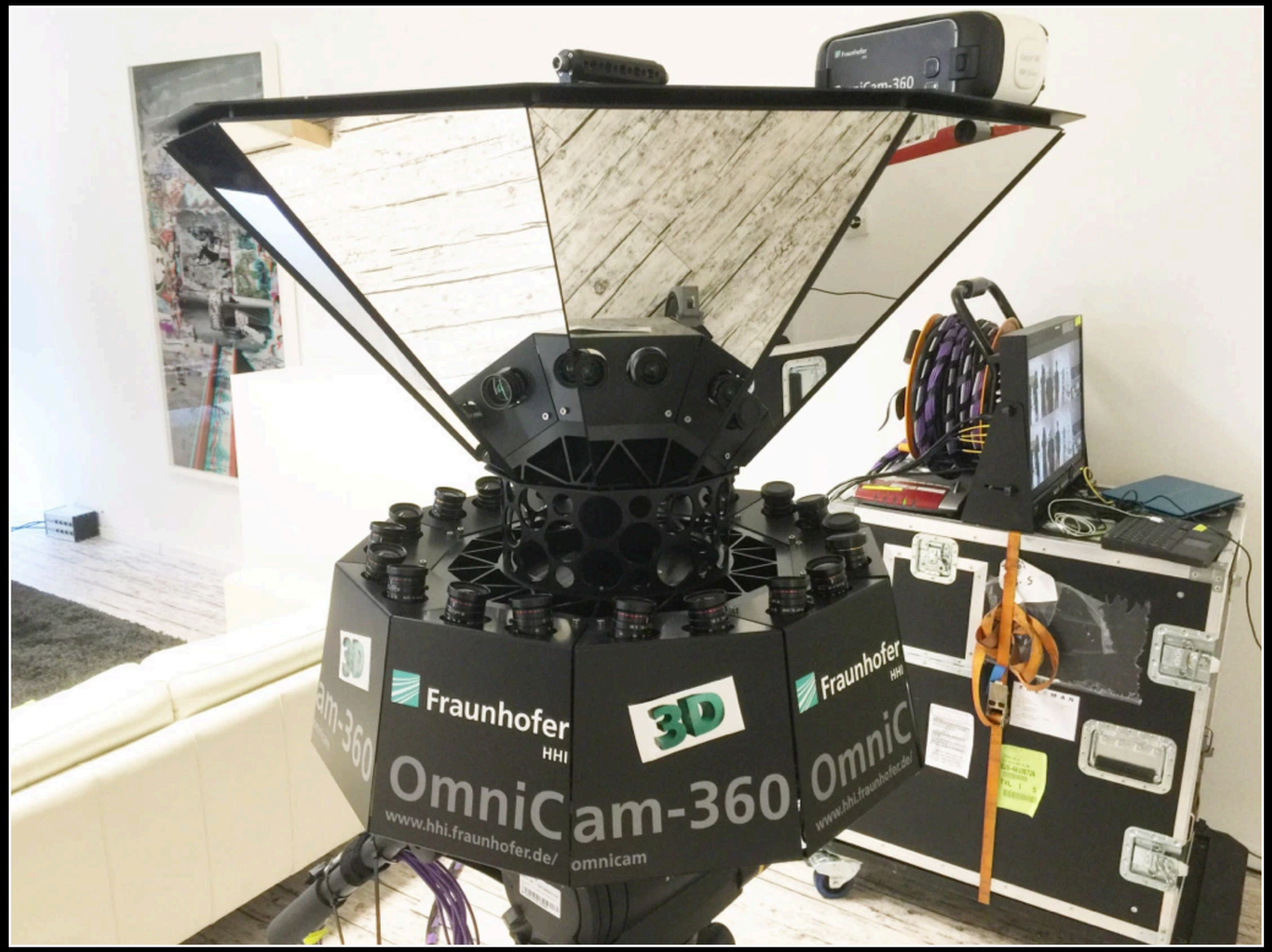
Solutions - Mirrors







Circlorama camera #2 (Disney)


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

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,283,653 A 11/1966 Tokarzewski
7,154,551 B2 * 12/2006 Kuriyama et al. 348/335

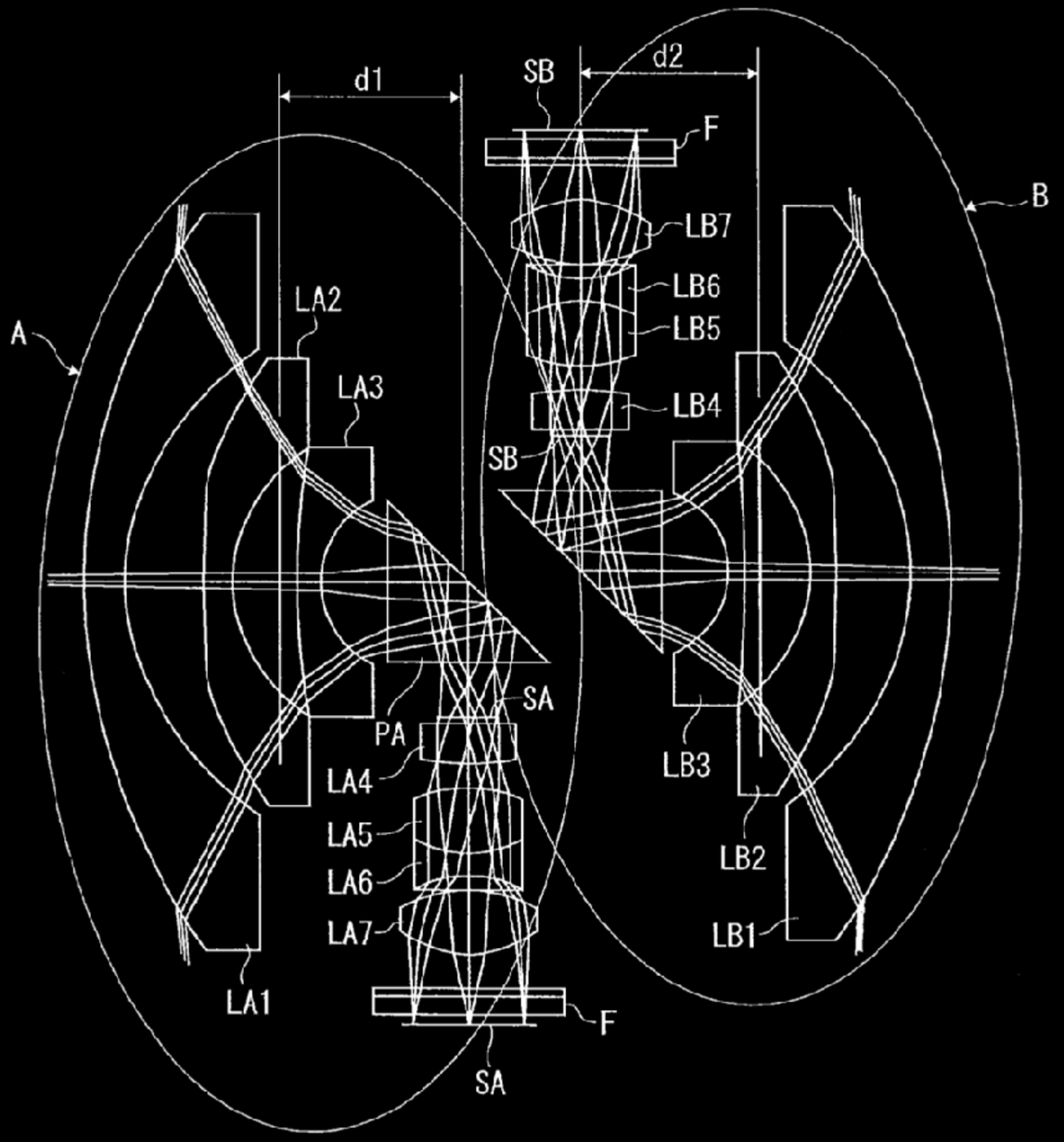
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2006-098942 4/2006
JP 2007-164079 6/2007

(Continued)

FIG. 1



Solutions - Custom Optics

E01
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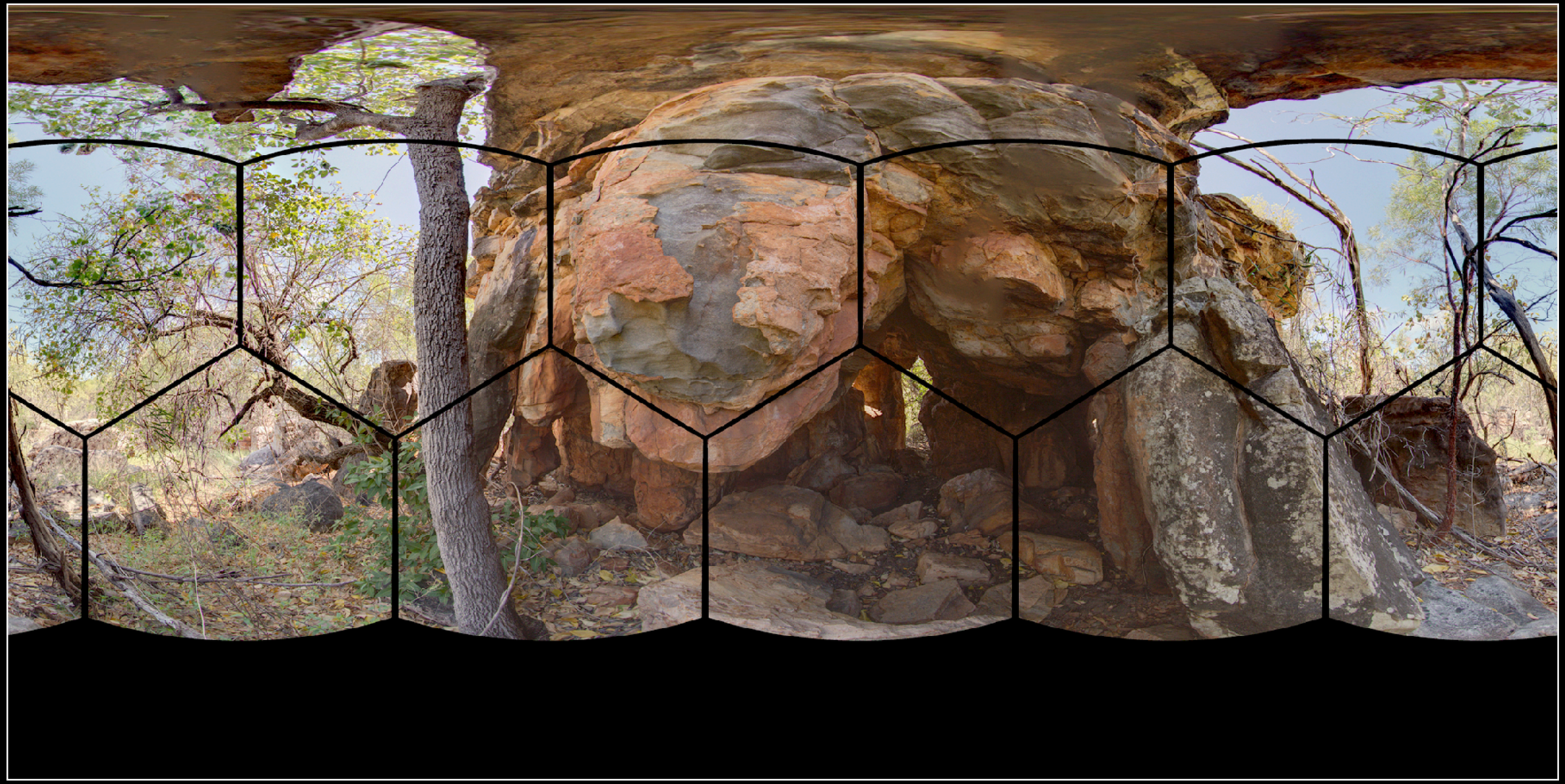

Solutions - Optical Flow

- 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.
- To facilitate this most camera have a lot of overlap between lens views.
- Perhaps one of the software 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:
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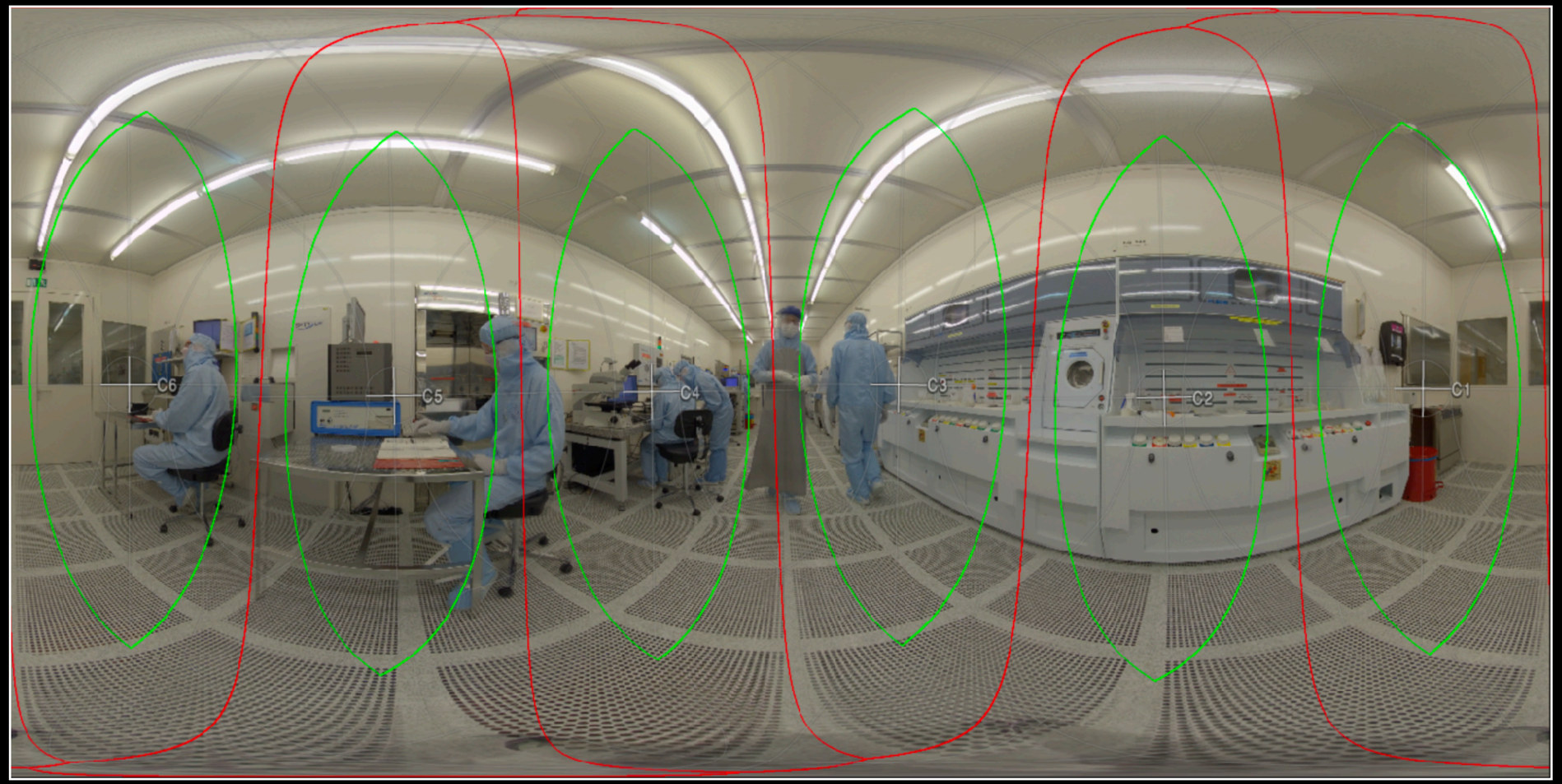
Undistort a:
Undistort b:
Undistort c: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C5
C4
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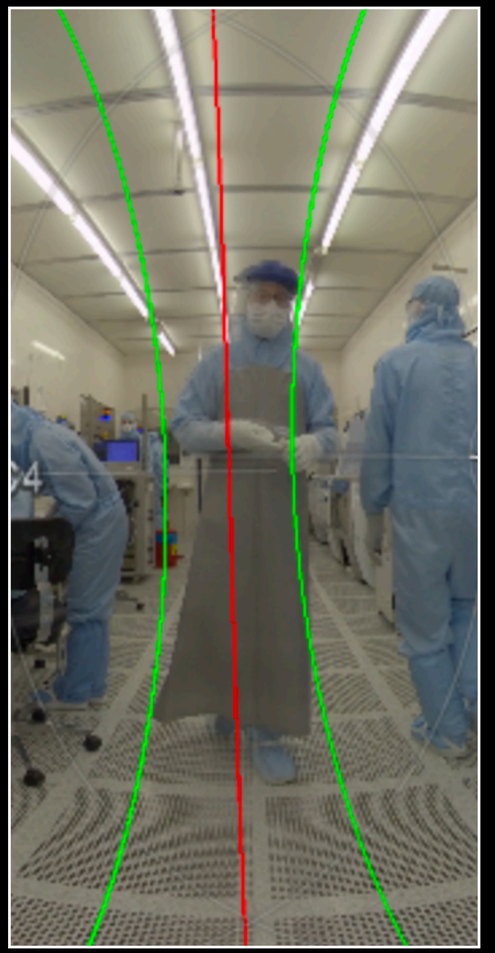
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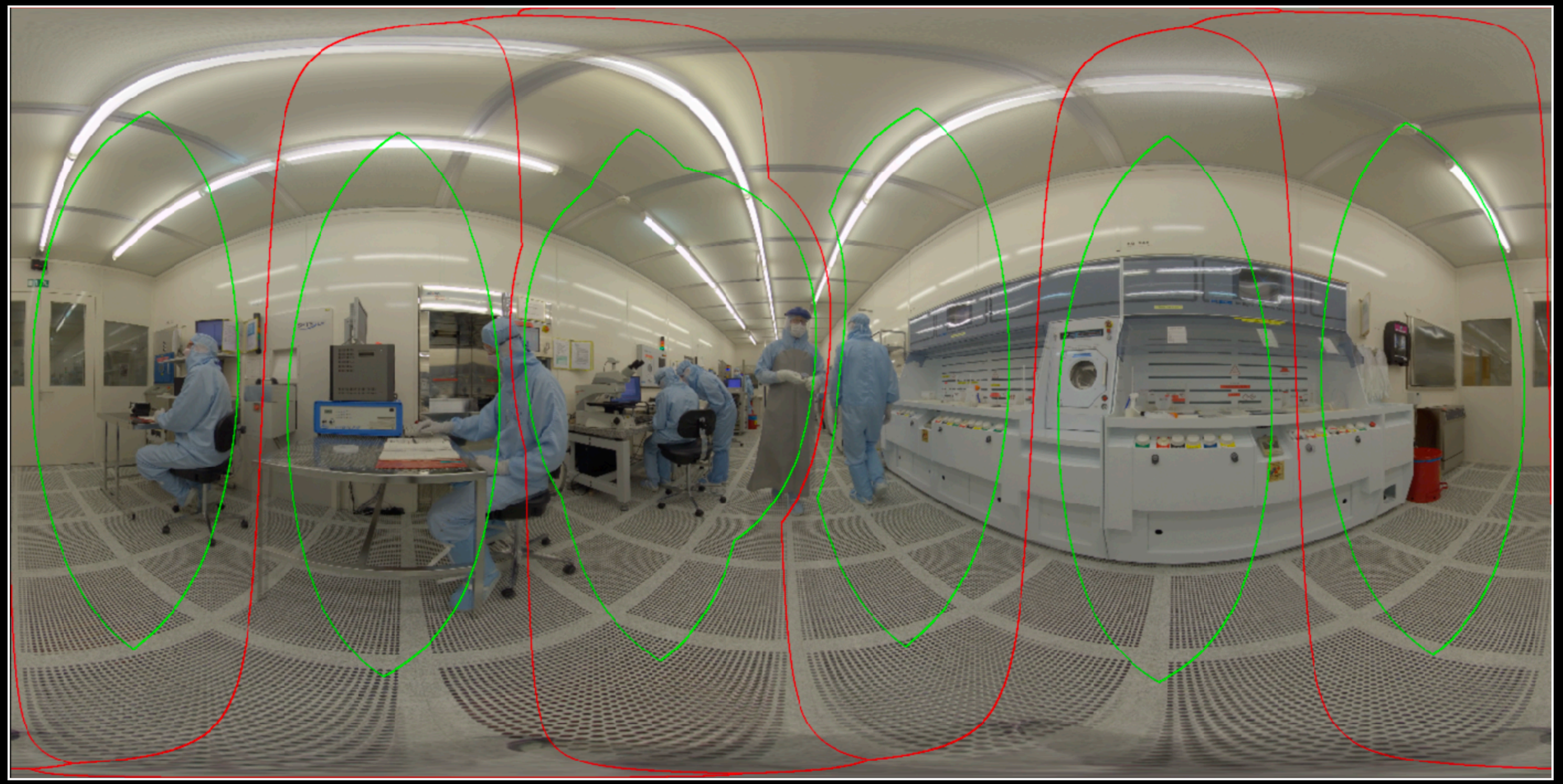
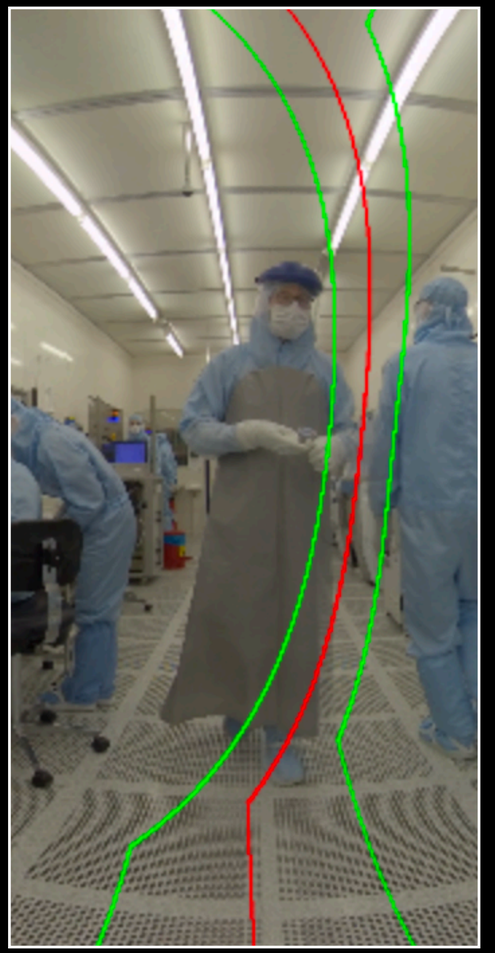




Miscellaneous topics - Resolution

- Currently equirectangular projections are the norm, resolution measured as horizontal pixels.
- Aspect always 2:1, 360 degrees horizontally, 180 degrees vertically.
- Most dual camera rigs are now around 5.7K pixels across, some are now 8K.
- Most of the multiple camera (>2) rigs are 8K.
  Including 8K in stereoscopic 3D.
- A few multiple camera rigs are now 12K, or greater.
- Most cameras to date have been just 8 bit, a few now and on the horizon are 10 or 12 bit.
- But like normal cameras it eventually becomes more about optical quality, dynamic range and camera reliability rather than purely resolution.

Miscellaneous topics - Audio

- No such thing as a boom mic on set!
- If one is recording 360 vision then 360 audio is also expected.
- Generally in-camera audio is terrible.
- Also issue of fan noise (cameras run hot) or limited recording time when fans turned off.
- Most common scenario is an ambisonic recording from the position of the camera (eventual viewer).

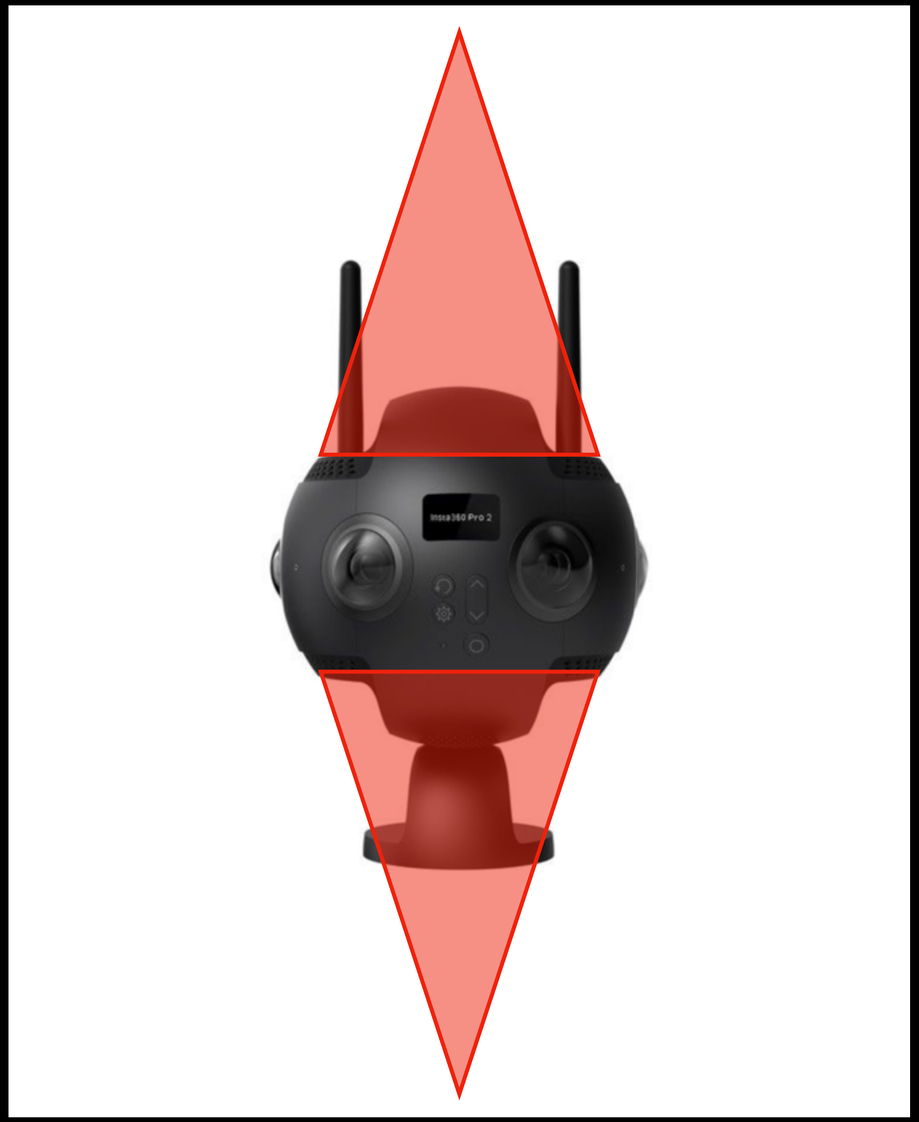

ZOOM
Manfrotto


Manfrotto

Miscellaneous topics - Lighting

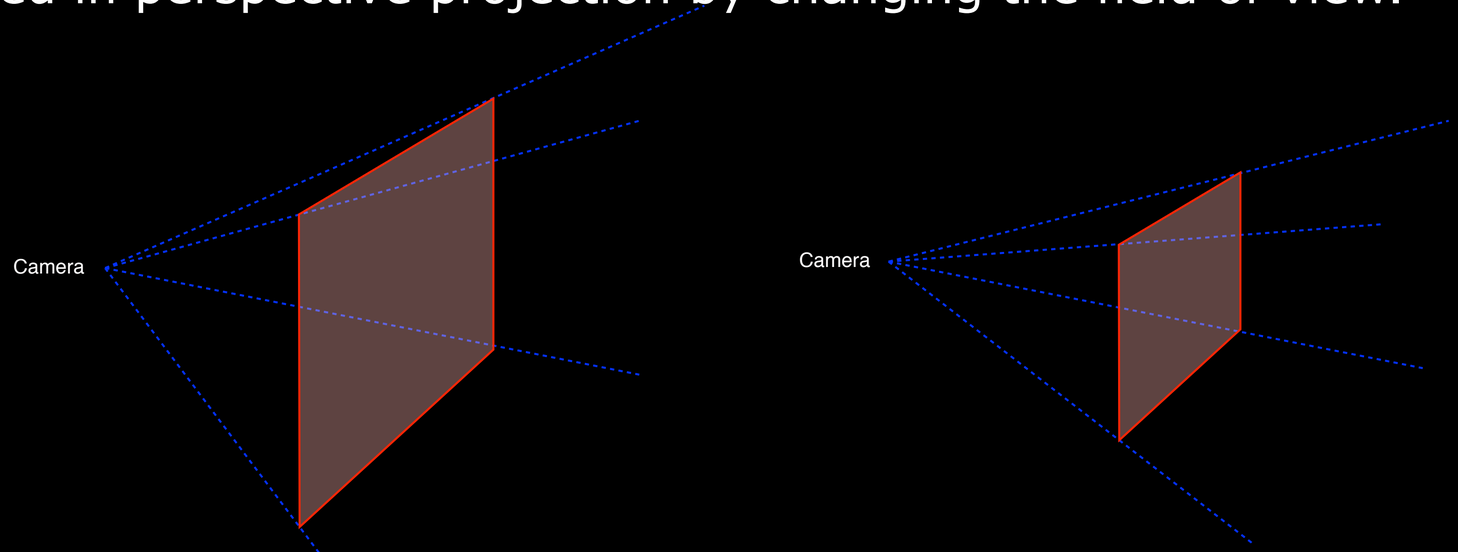
- Similarly, no space for lighting?
- Sometimes space under the tripod or in the visual dead zone above or below the camera.


Canon
moovi8
firefly


Insta360 Pro 2

Miscellaneous topics - Zooming

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



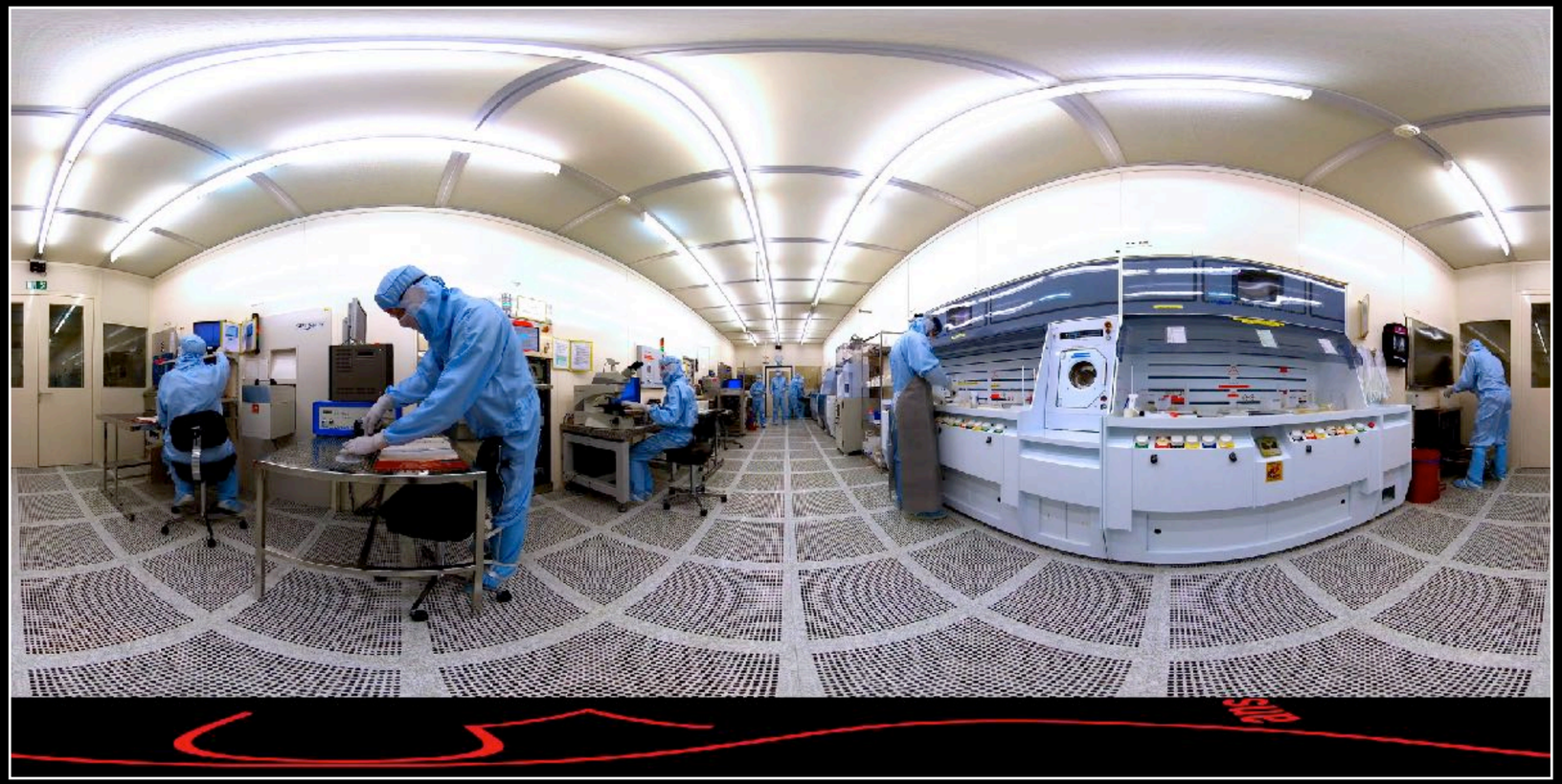
- To magnify something or to see more detail the camera needs to move closer towards it.

- 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 - Stereoscopic 3D (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.

Miscellaneous topics - It’s a new medium

- 8 years ago we had stereoscopic 3D movie peak, it failed to become ubiquitous, why?
  - Productions made stereoscopic because it was possible. Didn’t add to the storytelling.
  - Not exploit the opportunities, simply used their monoscopic techniques.
  - Not fully understanding the limitations, LOTS of really bad technical choices.
  - There are other reasons related to human vision … topic for another day.

- We now have another new storytelling tool in 360 video. But I see some of the same things.
  - Shooting as if it were directional.
    Hear questions like “*how to ensure someone is looking at the action?*”
  - Just because it is possible, doesn’t mean there are advantages in recording in 360.

- Lots of challenges.
  - Lack of large enough user base of 3D headsets.
  - Lack of a large collection of good content.
  - Many recording were made when camera hardware was more primitive.
  - Lack or large scale social environments, 360 theatres.

End - Questions?