Fulldome production seminar

Paul Bourke

Outline

- History
  - Domes
  - Digital projection
- Why a hemispherical screen?
- Perspective vs fisheye images
- Standards for fulldome video
- Content
  - Computer graphics
  - Photography
  - Video
  - Realtime and interactive content
- Differences between flat screen and fulldome
- Software
- Online resources
- Questions and demonstrations

Introduction

- Planetariums traditionally provide astronomy education, what could be seen in the night sky.
- Planetariums are increasingly adding "digital fulldome" support.
That is, a digital video that covers the whole hemispherical dome surface.
- Sometimes replacing dedicated star projectors, more often complementing the star projectors that generally still give a better representation of the night sky.
- Allows planetariums to educate in other areas of science, but also many other activities that may be referred to as entertainment.
- For digital content developers with a local digital planetarium this offers an exciting opportunity.

Personal background

- I'm not a filmmaker. I support researchers at UWA visualise their data. We use technologies such as stereoscopic 3D, high resolution displays, and domes.
- Initial work was in 2000 producing astronomy visualisation sequences for "Infinity Express", a SkySkan production. Flight over the surface of Mars and galaxy fly-through sequences.
- My main influence has been the invention of the spherical mirror projection system which is now in wide use around the world for smaller or modest budget installations.
- Secondary influence has been in the joint development of the iDome, a single person dome which also uses a spherical mirror.
- Personally interested in the use of domes as immersive environments for science visualisation.
- Produced a few science visualisation short movies.
- Co-produced some cultural/virtual heritage productions.
- Currently working on visualising astrophysical simulation for a production called "Dark", discussing DarkMatter and it's influence in the Universe.

History: Domes

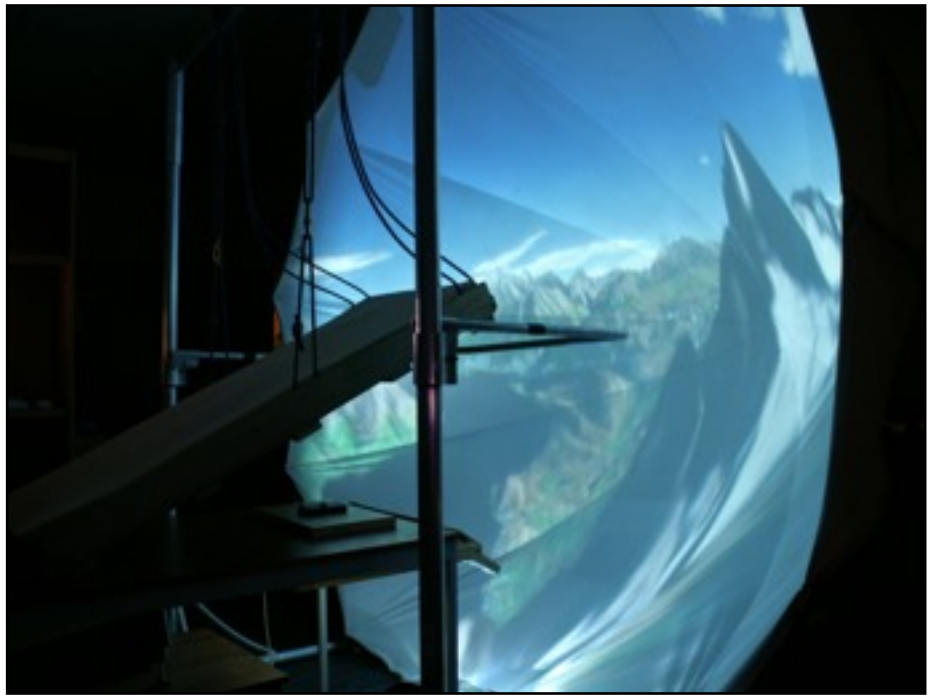
- 1500BC: Earliest known depiction of the night sky on Egyptian tomb of Senenmut.
- 500BC: First known domed building, called the The Dome of Heaven.
- 1923: First planetarium built in Munich, Germany.
  Projection using the Zeiss Mark 1 star projector.
- 1949: Spitz demonstrated their first star projector at Harvard College in the USA.
- 1959: First planetarium and star projector by GOTO of Japan.
- 1965: First star projector by Minolta of Japan.
- 1973: First OmniMax (iMAX) opened in Reuben Fleet Science Centre, based upon 70mm film.

History: Digital projection

- 1983: Evans and Sutherland develop a vector graphics style projector capable of creating points and lines at the Virginia Science Museum.
- Alternate Realities released the VisionDome in 1994.
  Elumens produced "personal domes", primarily as simulators for the military.
- 1997: Spitz install the first ElectricSky system in Canada comprising of 4 CRT projectors and edge blending.
- 1998: SkySkan demonstrates their digital projection system.
  The first digital video content not reliant on custom projection hardware.
- 2002: First laser projection system by Zeiss demonstrated in the largest digital dome at the time, 24m diameter.
- 2005: GOTO of Japan create the first full sphere projection system.
- 2008: SkySkan installs the first 8Kx8K projection system in the Beijing planetarium.
- 2010: SkySkan installs first stereoscopic 8Kx8K planetarium in Macau.

Dome types: inflatable domes

Dome types: small domes



Dome types: personal domes

Why a hemispherical screen?

- Historically it is the natural way to represent the night sky, 180 degrees x 180 degrees.
- Peripheral vision is one of the capabilities of our visual system that is not engaged when looking at standard flat or small displays.
- For all practical purposes our horizontal field of view is 180 degrees, vertical field of view is approximately 120 degrees.
- Note we don't necessarily see colour or high definition in our extreme horizontal field, it has evolved to be a strong motion detection mechanism. Our visual system does "fill in" the colour information for us.
- A hemispherical dome allows our entire visual field (vertically and horizontally) to be filled with digital content.
- We are used to seeing the frame of the image which anchors the virtual world within our real world. In a dome one often doesn't see that reference frame.
- The "magical" thing happens when one doesn't see the dome surface, more common in high quality domes with good colour reproduction. Our visual system, without any physical world frame of reference, is very willing to interpret representations of 3D worlds as having depth.

Dome projection

- Projection options listed roughly in order of resolution.
- Single projector
  - Fisheye lens
  - Truncated fisheye lens (see later)
  - Spherical mirror

- Twin projectors with partial fisheye lenses.

- Note that fisheye systems typically need to occupy the center of the dome.
- Multiple (typically 5-7) projectors located around the rim of the dome. The images are blended together to form a continuous image.
- As content developer one need not be (too) concerned with the projection technology.

Introduction to perspective theory

- Fundamentals of a perspective projection, the point on the projection plane is the intersection of a line from the 3D object to the camera.

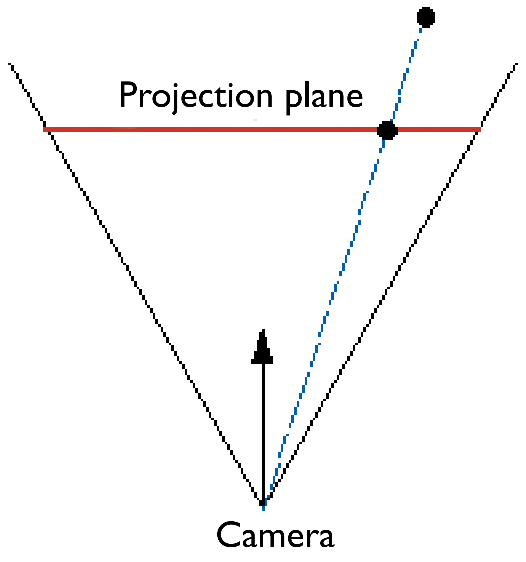
- Model of looking through a window.

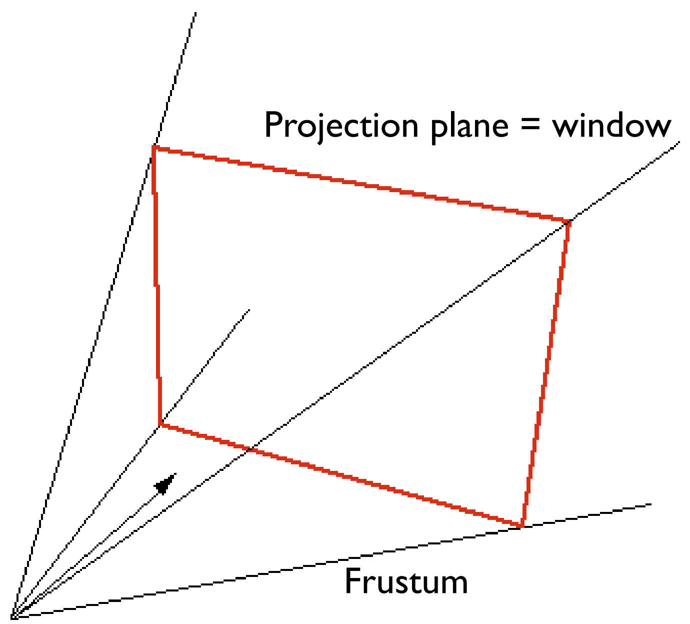
- A perspective projection is the simplest that captures the required field of view for presentation onto a rectangular region on a plane.

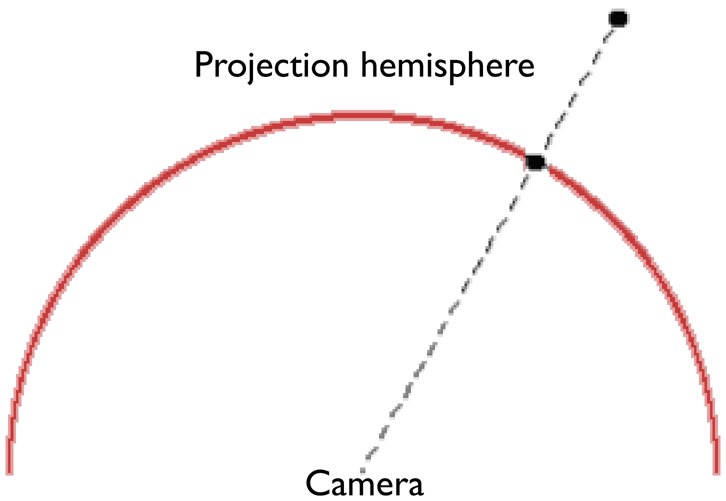
- Why isn't a perspective projection sufficient for a dome?
  - Doesn't capture the field of view required.
  - Not efficient to create a perspective projection > 120 degrees.

- Intersection of world objects with a sphere defines a fisheye or spherical projection.

- Fisheye projection is the simplest that captures the required field of view for subsequent presentation onto a hemispherical surface.







Understanding a fisheye view

Back rim of the dome

Center of the dome

Left rim of the dome

Right rim of the dome

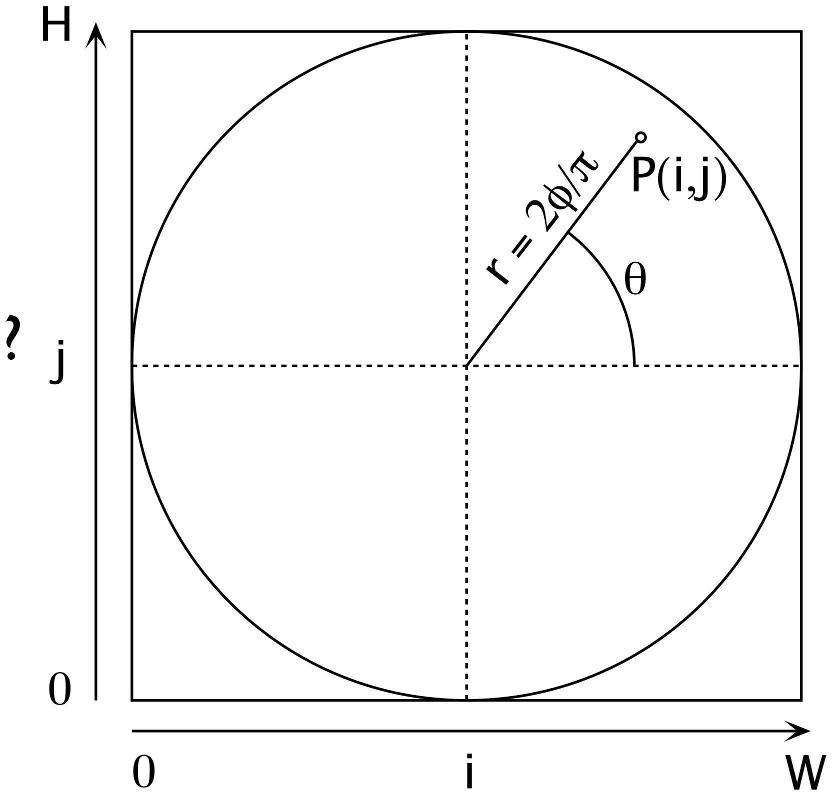
Rim (spring line) of the dome

Front rim of the dome

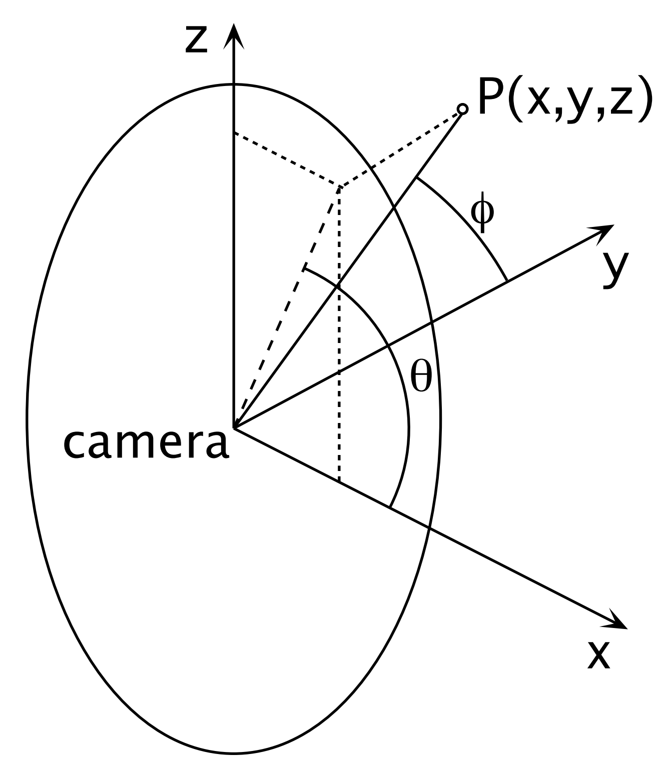
Mathematics of a fisheye image

- Typically need to relate the mapping to/from fisheye image coordinates (2D) to a world vector (3D).
- 1. Given a point P(i,j) on the fisheye image (in normalised image coordinates), what is the vector P(x,y,z) into the scene?
  r = sqrt(Pi2 + Pj2)
  theta = atan2(Pj,Pi)
  $\Phi = r \pi / 2$
  $Px = \sin(\Phi) \cos(\theta)$
  $Py = \cos(\Phi)$
  $Pz = \sin(\Phi) \sin(\theta)$
- 2. Given a point P(x,y,z) in world coordinates what is the position P(i,j) on the fisheye image?
  Φ = atan2(sqrt(Px2 + Pz2), Py)
  $\theta = \mathrm{atan2}(Pz, Px)$
  $r = \Phi / (\pi / 2)$
  $Pi = r \cos(\theta)$
  $Pj = r \sin(\theta)$
- Traditional to limit the fisheye image to a circle but it is defined outside the circle.

Fisheye image



3D vector into scene



Fulldome video: Standards

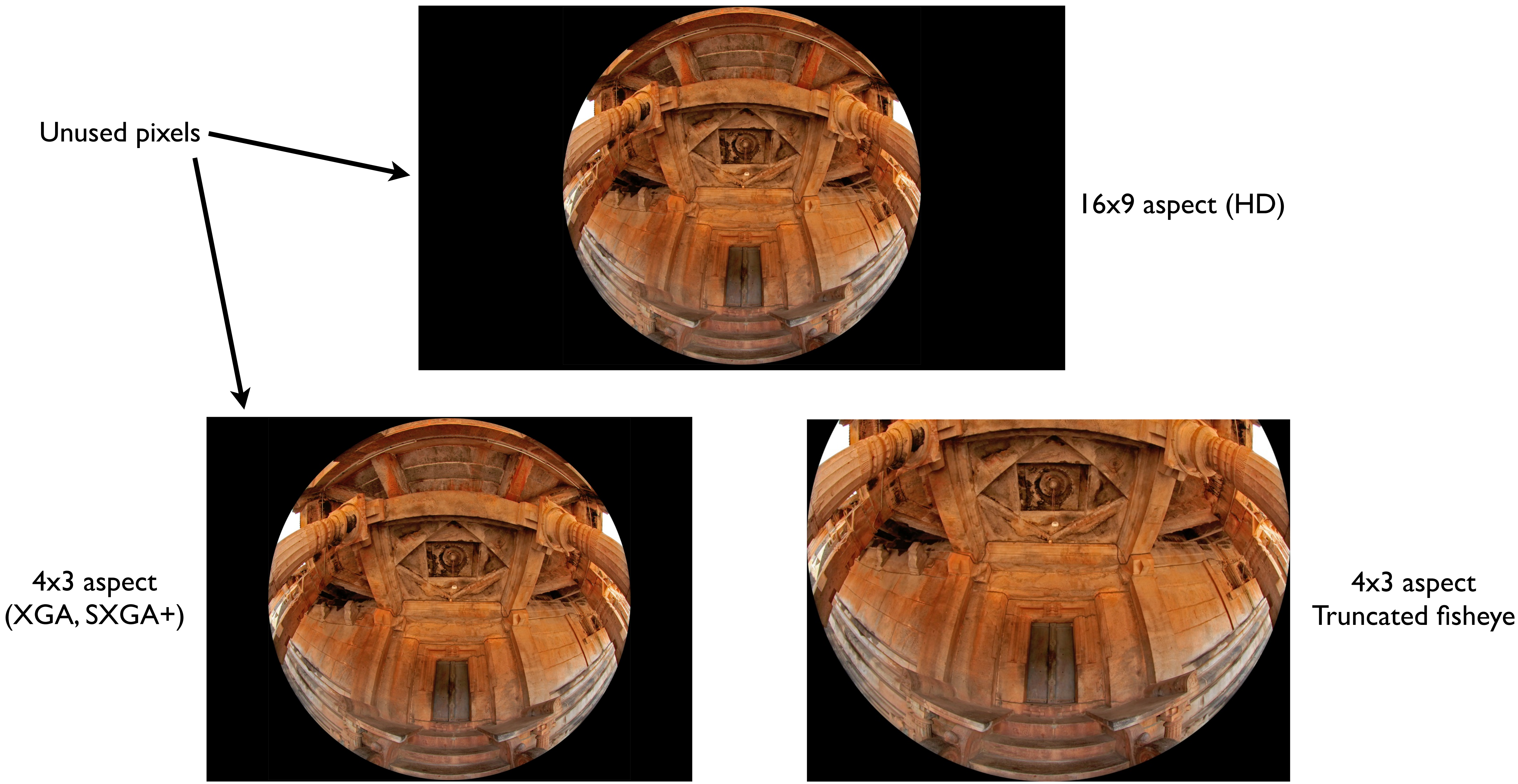
- 30fps is the norm (actually 30, not 29.97 of NTSC). Square pixels.
- Orientation of the fisheye frame, see image bottom-left.
- Unfortunately no good gamma or colour space specifications (gamma, white point, temperature).
- Audio requirements are quite variable between installations, from simple stereo in small domes to 7.1 systems.
- Not uncommon to place information within the unused portions of the circular fisheye frame. Eg: frame number, sequence name, author ... no standards.

Resolution: single projector systems

- Resolution for more single projector systems is between 1024 (1K) to 2048 (2K) pixels.
- Square pixels, reflects the CG (instead of filmed) history of fulldome.
- Progressive frames, interlaced has never been used.
- Small planetariums with a low end fisheye system may not be able to represent more than a 1K square fisheye. Some single projector systems can represent 2K.
- Spherical mirror content with a good HD projector can represent up to 1600 pixels.
- Difficult to compare resolution between some technologies, the systems quoted resolution is generally not the same as the actual available/perceived resolution.
- Content normally supplied as movies, QuickTime or some MPEG variant.

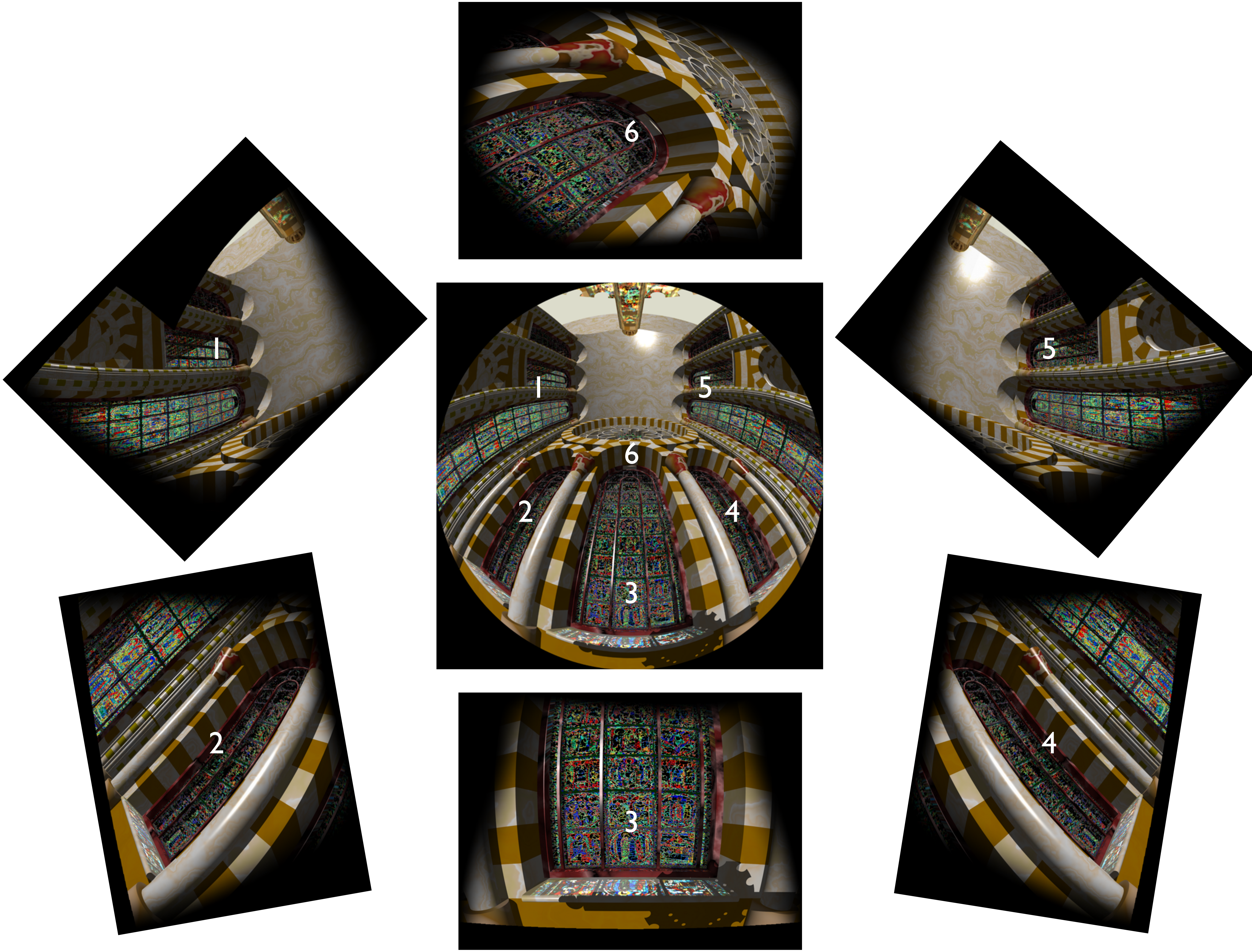
Dome projection: truncated fisheye

- For fisheye lens projection the circular fisheye image needs to be inscribed within the projector frame.
- This can be very inefficient use of pixels, most are not used. Especially true for current HD projectors.



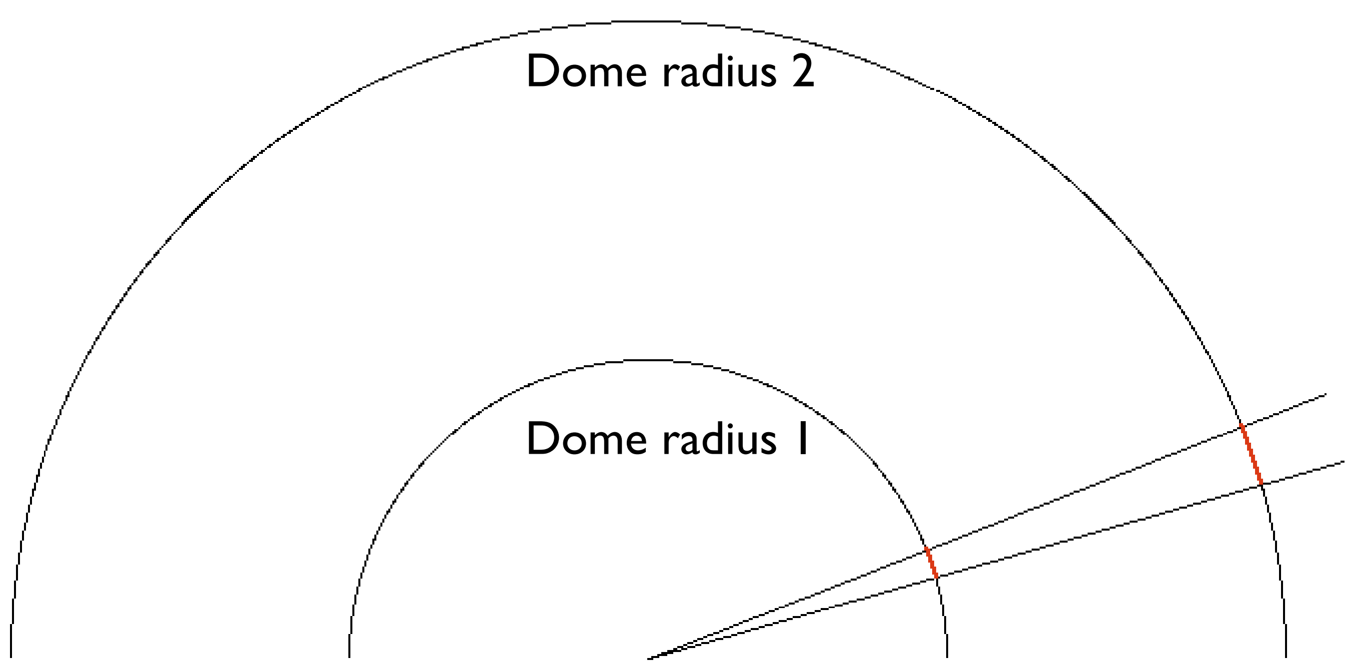
Resolution: multiple projector systems

- Frame resolution for multiple projector systems has been increasing from 2400, 3200, 3600, 4096 (4K).
- Most productions now mastered at 4K pixels square = 16 MPixels.
- Expectation by planetariums who have invested in high end systems to receive material at that resolution.
- Some planetariums today can present 8K square images.
- Difficult to compare resolution between some technologies, the systems quoted resolution is generally not the same as the actual available/perceived resolution. For example: edgeblending is rarely perfect, the edgeblended seam often looks "soft".
- Content normally supplied as individual uncompressed frames (TGA, PNG, JPEG at 100%) along with a matching length soundtrack.
- Important to realise that in all cases content is supplied as fisheye images, anything that needs to be done to those to make them playable is the responsibility of the installation. Generally only they will have the software and the calibration information necessary.


6
1
5
1
5
6
2
4
3
2
3
4

Resolution

- Interesting to consider that for a given image resolution the size of the dome does not change the perceived resolution. The angle a pixel subtends at the eye is the same irrespective of the dome radius.
- Difficult to compare resolution between some technologies, for example, current digital projectors (if in focus) can result in individually resolved pixels on the dome, this is not necessarily the case for analog CRT systems.
- How does one compare resolution when there are screen door effects on some projectors.
- Some knowledge of the dome resolution of the target system is relevant to content production as it determines the finest detail that can be represented.
- More important than resolution is how it is used!
  Good content can hide low resolution projection



Resolution

- Cannot necessarily create high definition 4K fisheye images and expect to be able to down sample for a lower resolution installation. Especially true for high definition content converted to single projector systems, fine detail can be lost in the antialiasing that occurs in a downsampling process.

- The same applies to detail within 3D models, fine detail that can be resolved in a 4K render may not be resolved in a 1K render due to aliasing effects.

- Resolution on the dome does not necessarily have a 1:1 correspondence with the resolution of the source fisheye images, for example most system employ lossy compression codecs.

- Estimates vary but the human visual system can resolve down to around 3 arc minutes. Surface area of a hemisphere is 2 pi r^2 so 3 arc minute resolution needs about 13 MPixels.

- Opinions vary regarding the importance of ultra high resolution compared to the story telling component/skill. At what stage does the resolution not become the determining factor to the experience?

- Current discussion as to whether 60Hz frame rates would be of greater benefit than high resolution.

Computer graphics

- Most animation/rendering packages support a circular fisheye lens or there is an external plugin.
- Where this isn't the case the most common approach is to render cubic maps and post process those to form a fisheye.
- Can choose to render between 4 and 6 faces of the cube to and postprocess to generate a fisheye.
- See "cube2dome", my stitching software, "Glom" from Spitz, and others.
- An implication to animators is they need to model more of the world than they might normally do because of the wider field of view.

Computer graphics

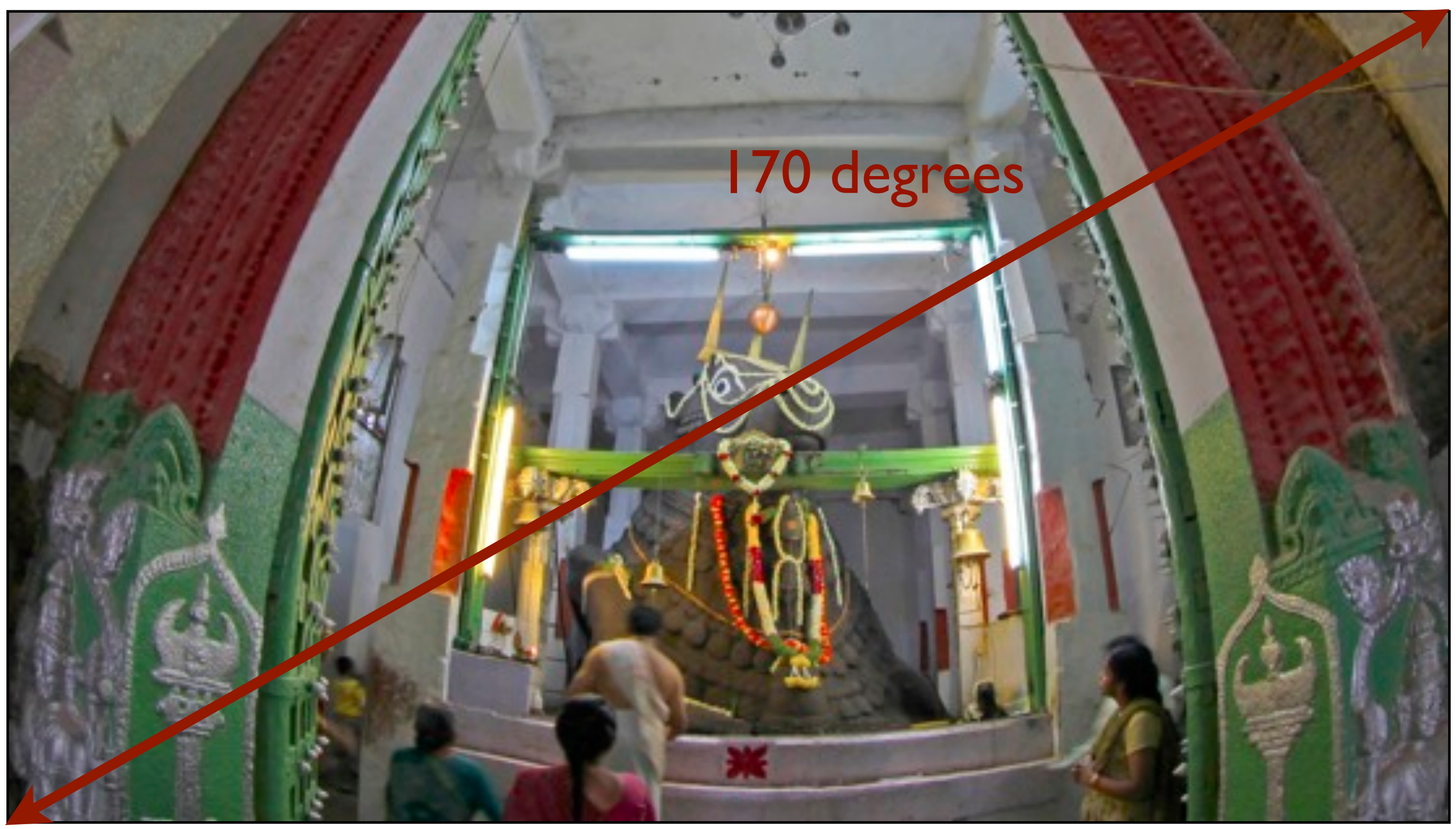
- Using cubic maps has the added advantage of being able to change the view direction in postproduction.
- For example, to correct for dome tilt angle.
- Can also pan around within high resolution cubemaps.

Challenges

- Need to model in detail much more of the scene than needs to be done for a "normal" limited field of view perspective projection.
- The requirement to render very large frame sizes compared to more traditional media. The most common format for widely distributed content 4096x4096 pixel fisheye images is the standard.
- That is 8 times the number of pixels per frame compared to a HD (1920x1080) resolution animation.
- Access to render farm with your rendering engine of choice.
- Lack of easy preview options. Small domes and projection systems are rare and relatively expensive, time in many digital planetariums is valuable.

Photography

- Simplest way is a single (usually SLR) camera and fisheye lens.
- Distinction between wide angle fisheye lenses and circular fisheye lenses.
  For example a 170 degree wide angle fisheye is usually the angle between the diagonals.
- As with fisheye lenses on projectors, the main issue is detail and chromatic error towards the rim.

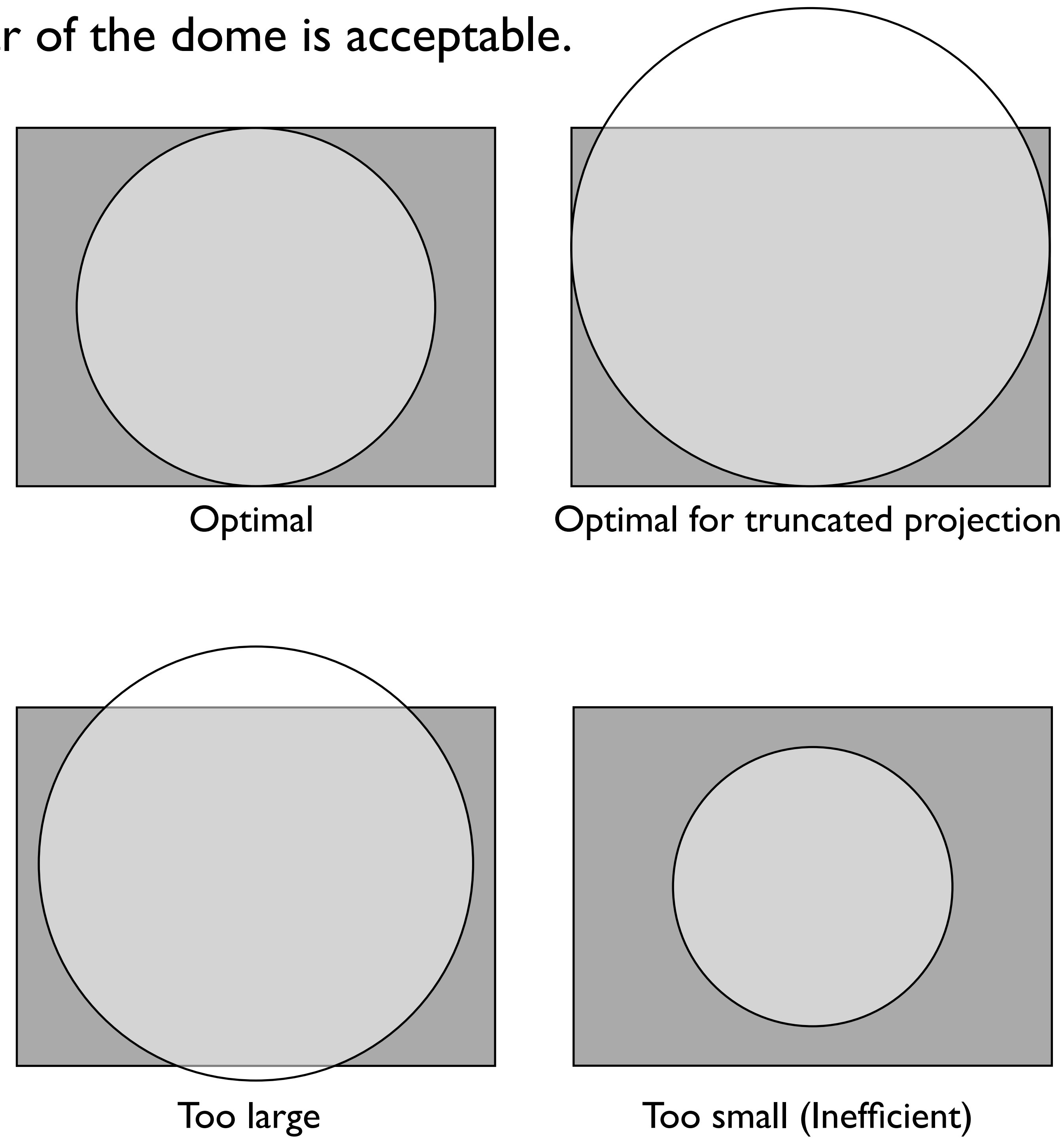


170 degree wide angle fisheye


Circular fisheye

Photography: sensor size

- Consideration of how much of the sensor is being used or if the fisheye is truncated.
- Generally limited by the vertical resolution of the sensor.
- Sometimes truncation at the rear of the dome is acceptable.



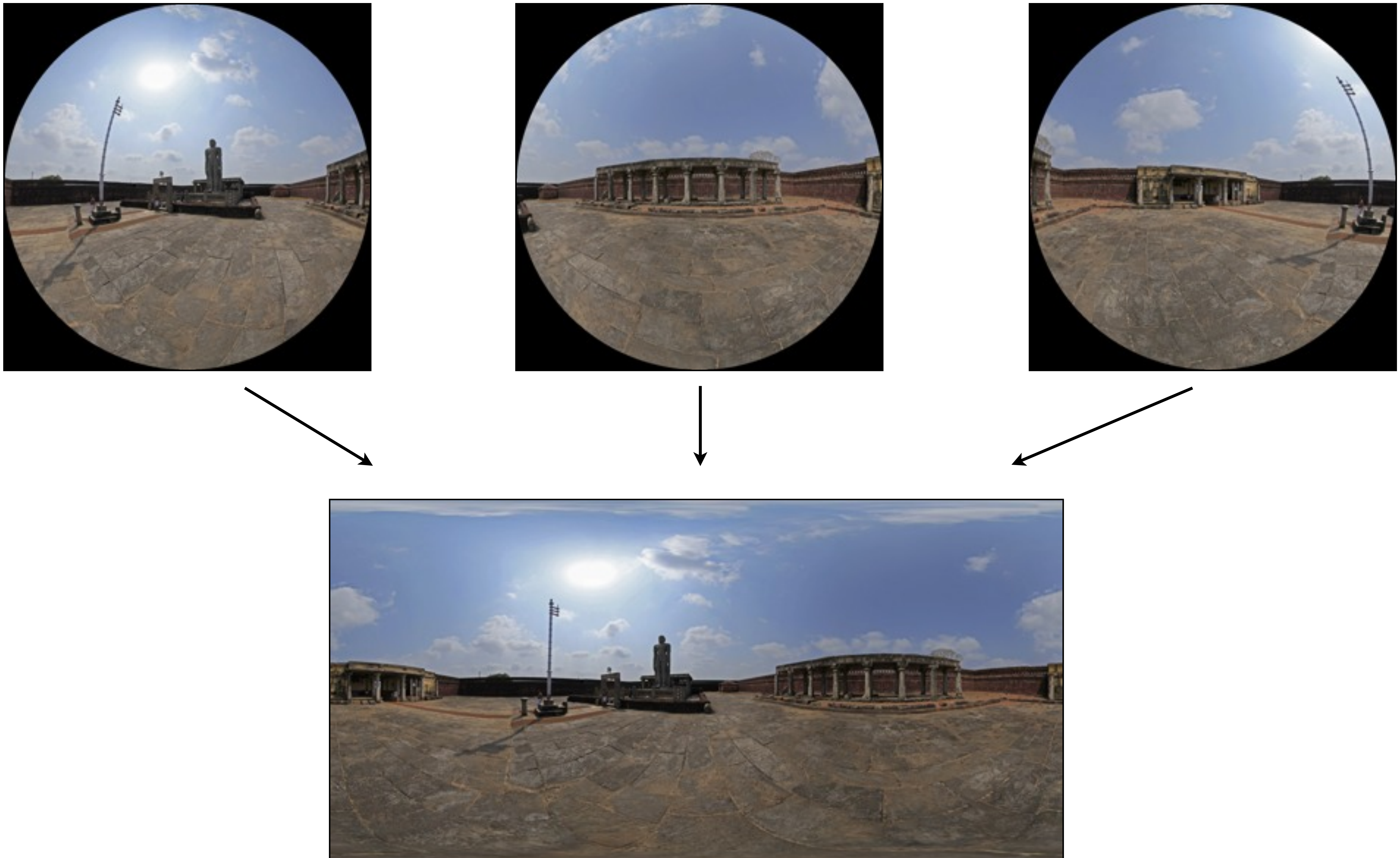
Photography: sensor size

Example of a full frame fisheye on a 2/3 sensor

Example of a 2/3 fisheye on a full frame sensor

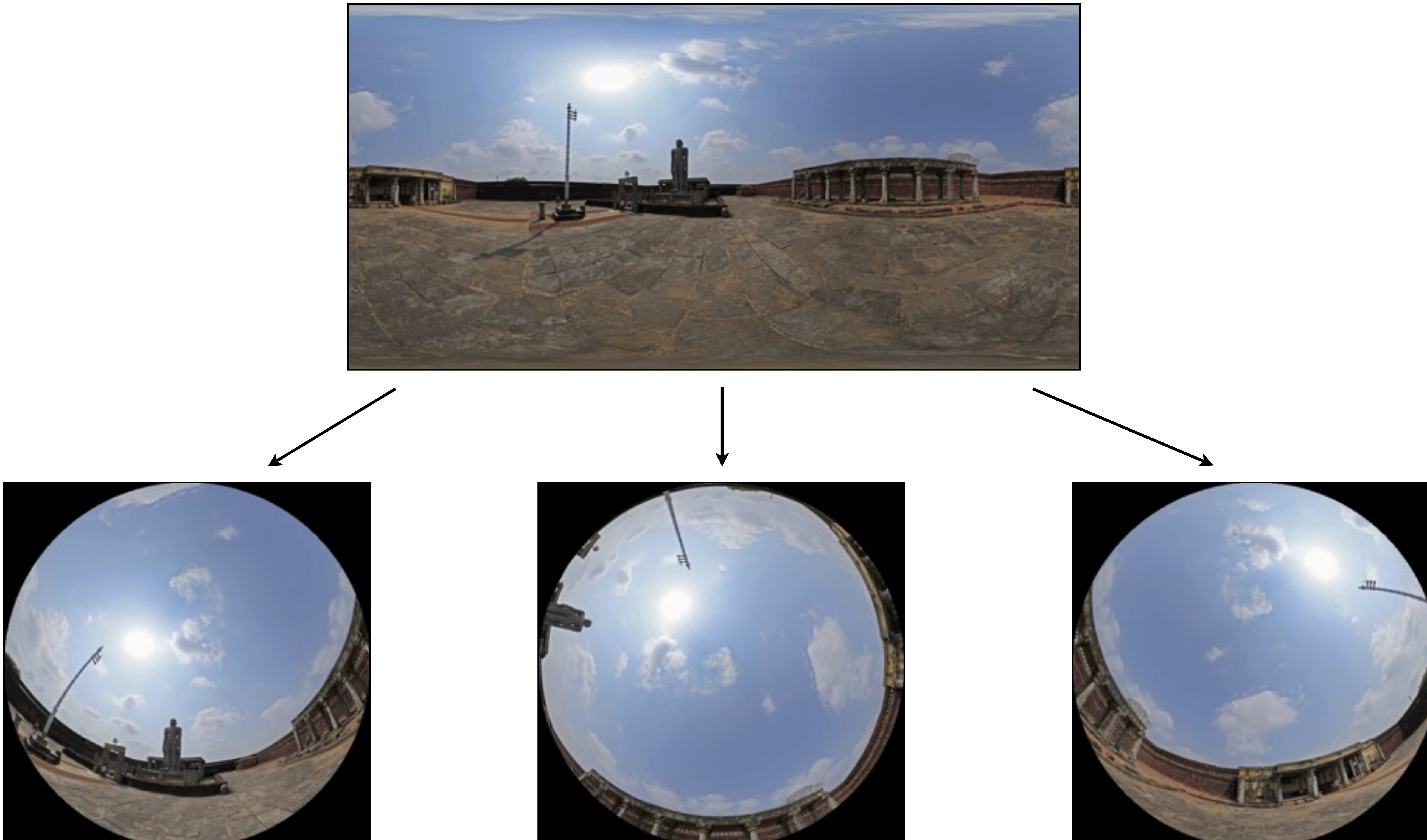
Ideal, 2/3 fisheye on a 2/3 sensor,
or full frame fisheye on full frame sensor

Photography: spherical projections



Photography: spherical projections

- Same as cube maps earlier, any fisheye view can be created from on spherical image.



Filming

- Much more difficult to achieve sufficient resolution.
- 1K easy, 2K more difficult, higher resolution much more difficult.
- Note that resolution is not solely related to sensor resolution, video cameras apply lossy compression.
- Fisheye lens can be mounted on some video cameras but still difficult to find a high quality solution. Commodity video cameras and SLR cameras are generally 1080p which limits the diameter for a full fisheye. 4K video cameras may be interesting in the future.
- For some applications top truncated fisheye video can result in increased resolution, using more of the sensor.
- Full fisheye vs partial fisheye, same issues as with fisheye projection: truncated or inscribed fisheye. Partial fisheye circles may be acceptable for domes with directional seating.
- Issues of lens quality, chromatic error and focus issues on the rim.
- Same issues with fisheye image and sensor size as discussed with still cameras.

Filming: multiple camera rigs

- Current solutions for high resolution fisheye are generally unwieldy.
- Require mains power and large hard disk arrays.

- Some people have experimented with multiple commodity cameras (eg: GoPro), or multiple SLR cameras. The multiple images are stitched together to form a single fisheye or spherical image. Not straightforward!
- 4K video cameras will give a 2K fisheye.

Filming: LadyBug

- Captures a full 360 degree field of view horizontally and about 145 degree field of view vertically. A partial spherical image.
- Capturing more than we need but it means we can choose the exact the exact fisheye view in post production. Same advantages as discussed for cubic maps for computer generated material.
- Resolution of the spherical projection is 5400 x 2700 pixels. Translates into fisheye images around 2300 pixels square. This does not take into account the video style compression artefacts that occur.
- Limited to 16fps. The earlier LadyBug-2 was 30fps but lower resolution.

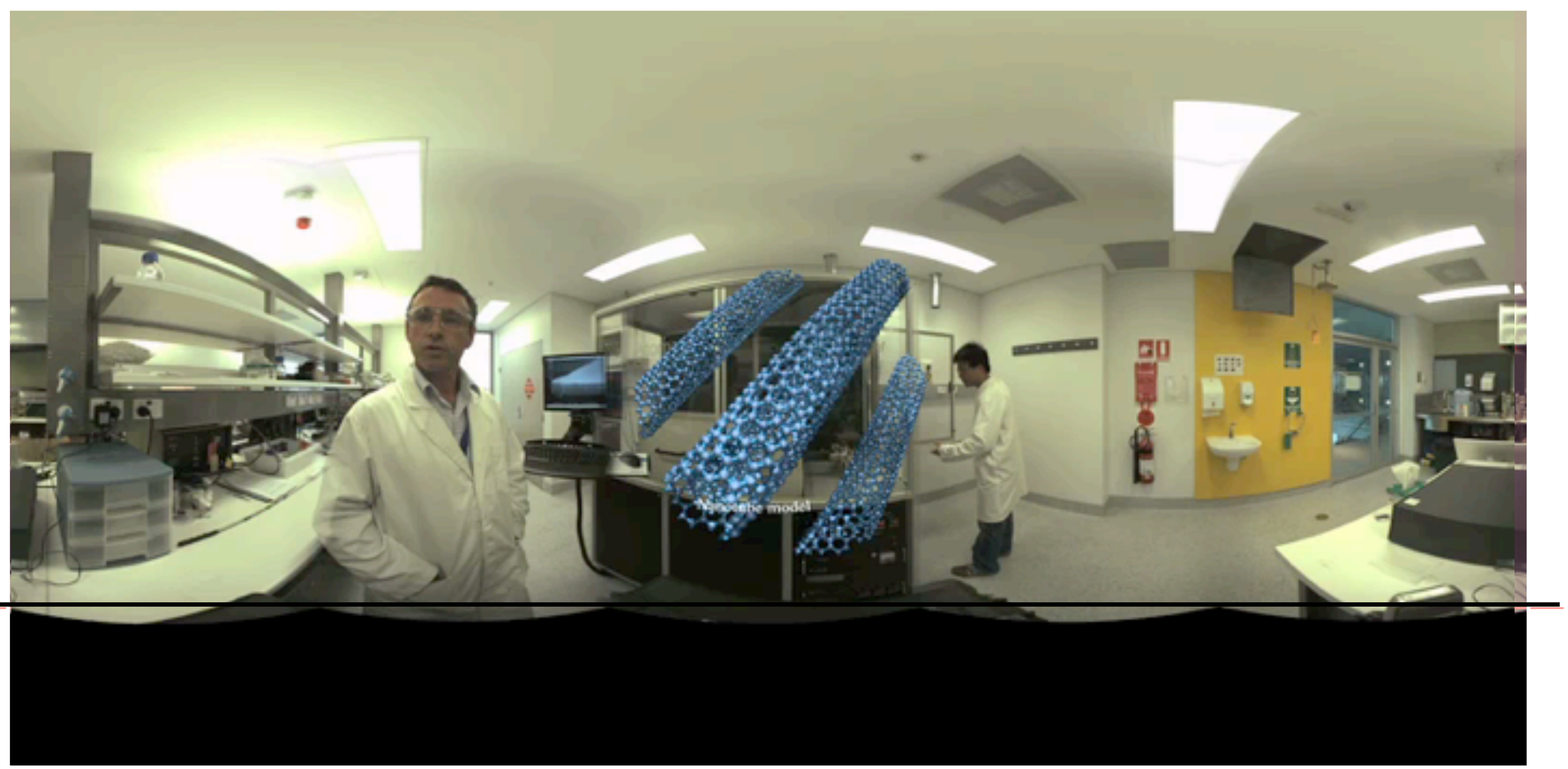
Spherical projection

Courtesy Volker Kuchelmeister, iCinema

One possible derived fisheye

LadyBug-2

Filming: LadyBug-3

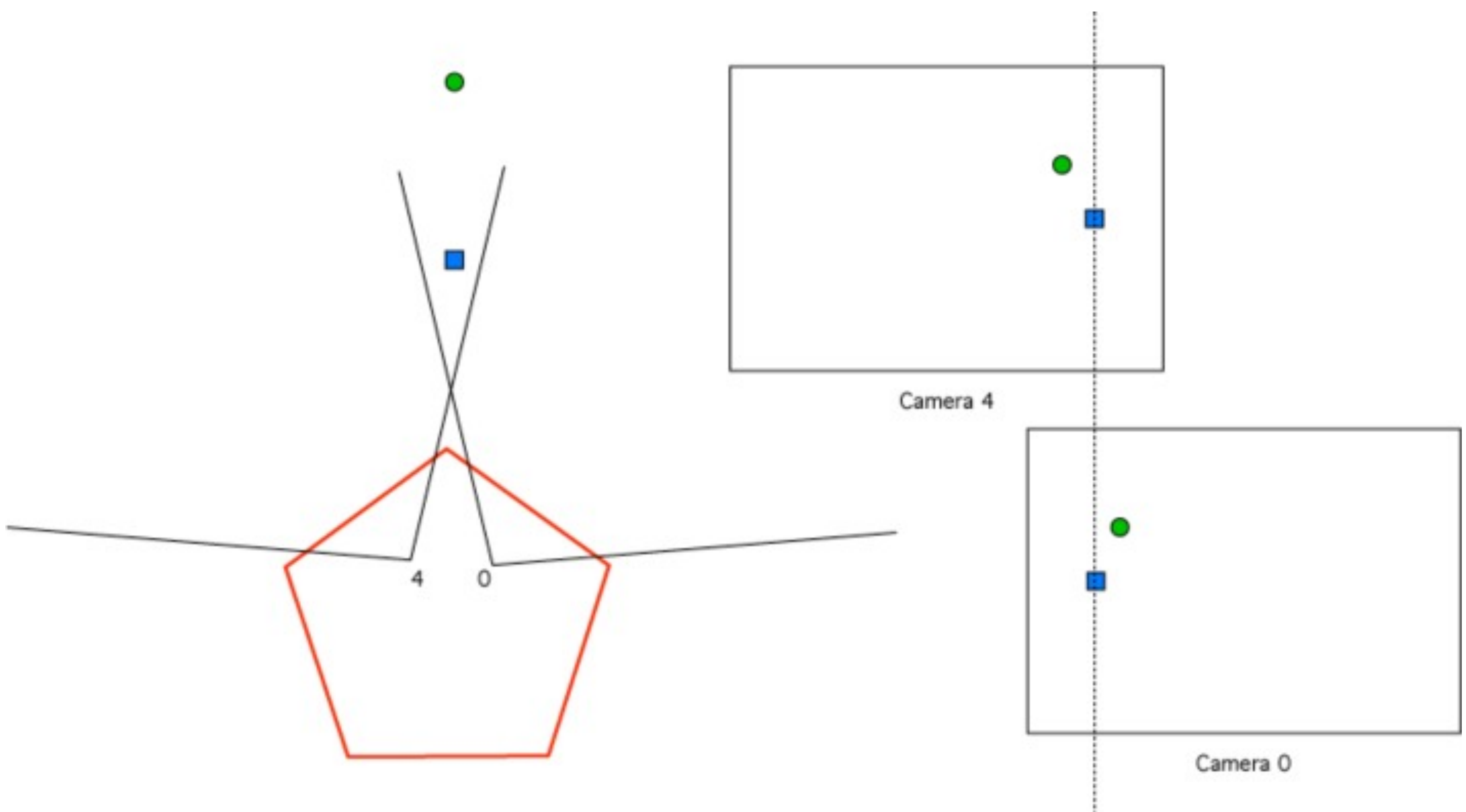


-50

Filming: LadyBug-3

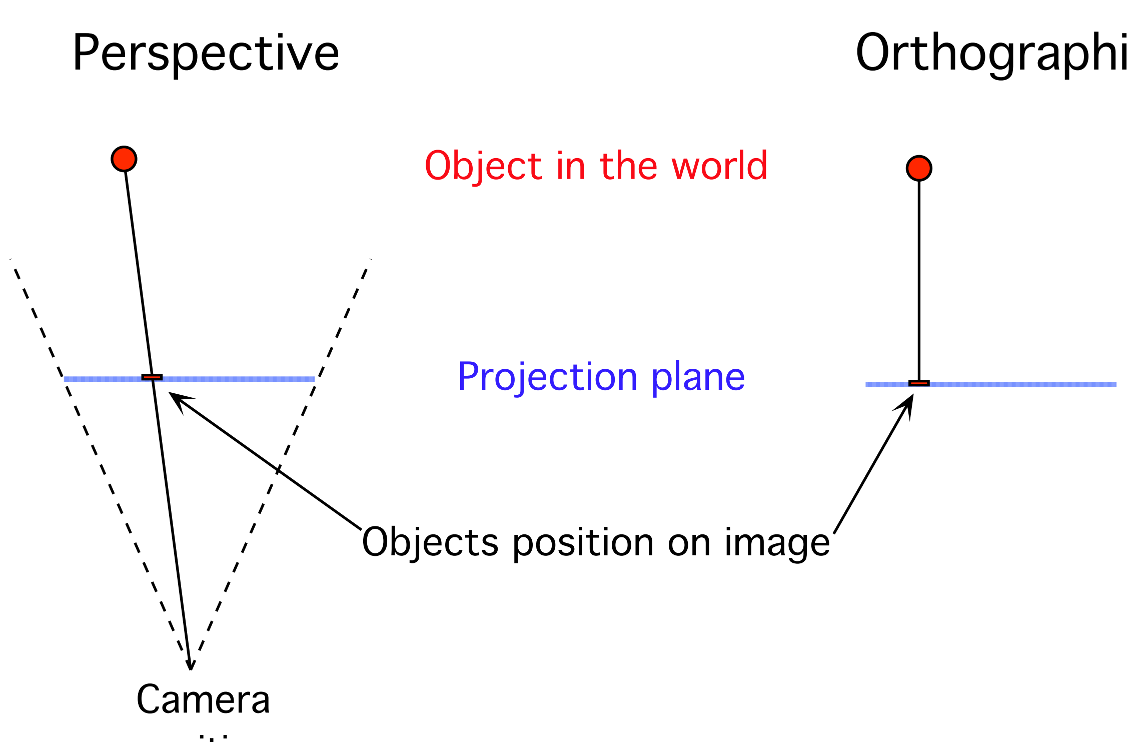
- Some blurring on the camera seams.
  For fundamental reasons (out side the scope of this discussion) it is impossible to have a perfect seam at all depths. It is possible to have a perfect seam at one particular depth.

- Using the LadyBug-3 at full resolution in the field requires
  - Power source, eg: car battery.
  - Inverter to get AC from DC battery.
  - External fast hard disk.
  - Laptop.



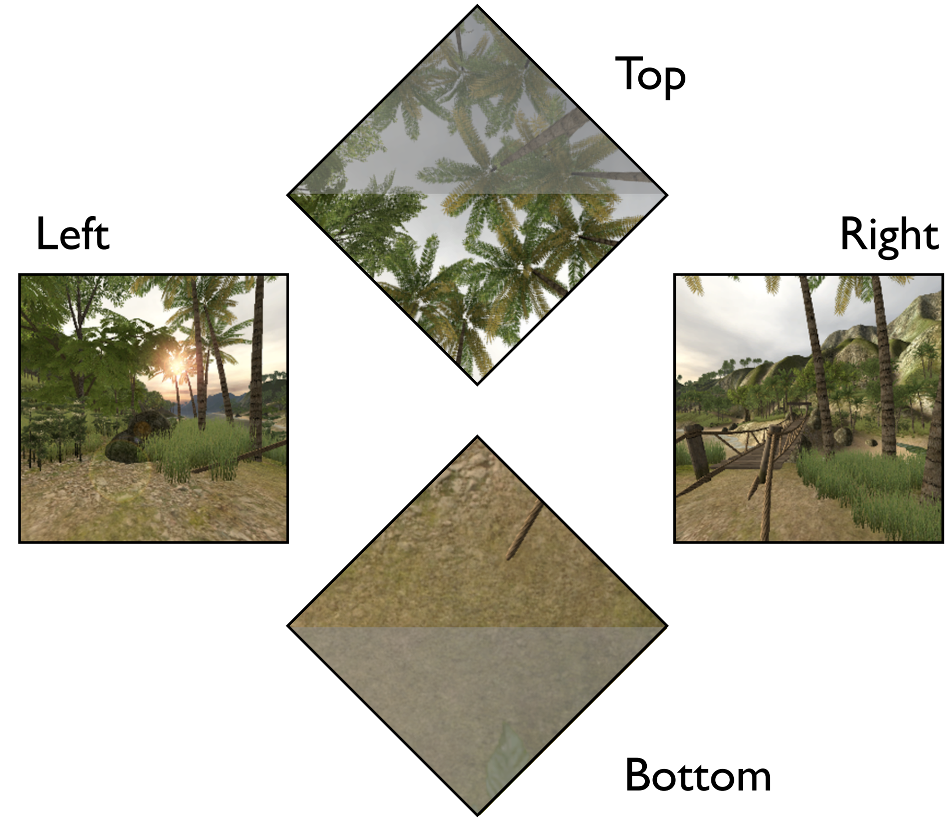
Realtime and interactive

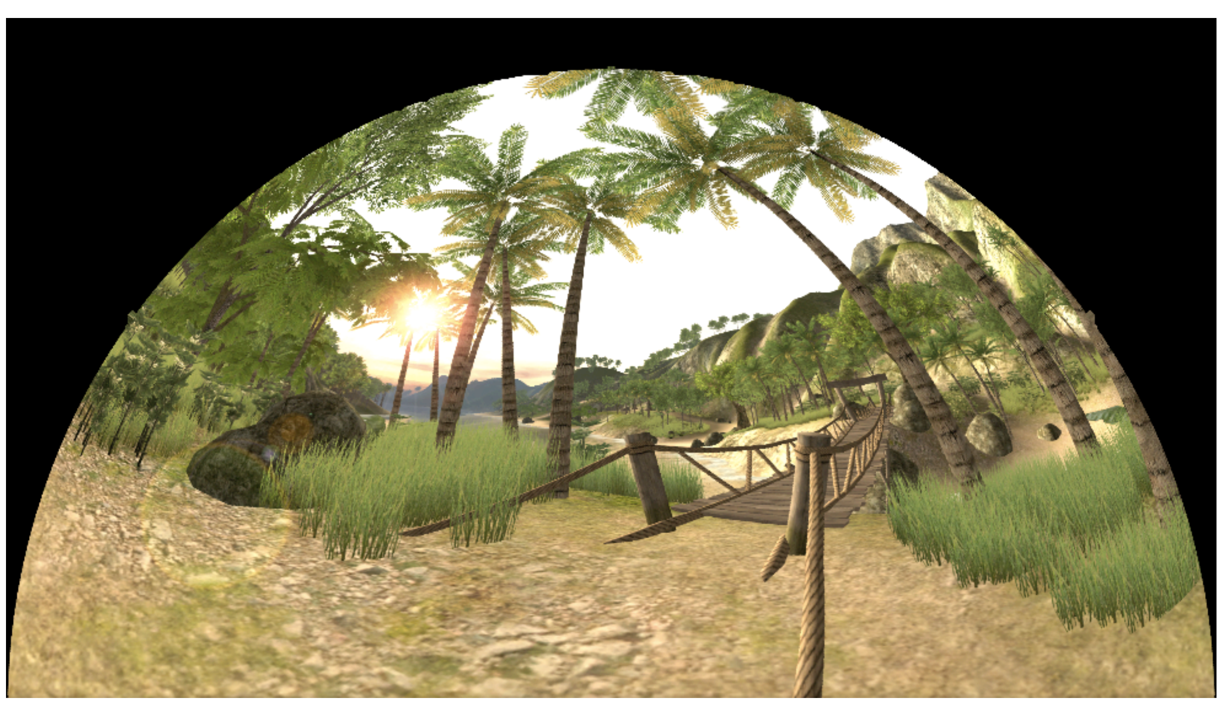
- This talk is primarily aimed at movie content.
- While realtime APIs such as OpenGL and DirectX cannot create fisheye directly they can do so by either using the same cube map technique or using vertex shaders.
- Most planetarium suppliers have interactive applications for visualising astronomy data from the scale of planets up to the larger scales in the Universe.
- Perhaps the most popular small dome package with fisheye support is Stellarium (Open Source), also in a parallel development stream called Nightshade.
- Some engines (such as Unity and Quest3D) have a powerful enough scripting language to create the fisheye (approximation using a spherical reflective sphere).



Realtime: multipass textures

- The most straightforward approach and often the easiest to integrate into existing software.
- The scene is rendered 4 times and the resulting images, instead of being displayed, are mapped onto a mesh that creates a fisheye projection when rendered with an orthographic camera.





Warped fisheye

Fisheye

Variations between installations

- In reality, for an optimal result, one does need to know certain details of the final projection environment. During content creation it is important have access to the final projection installation for previewing, critical at the start of the process.

- Differences due to variations in projection systems:
  - Resolution capability of projection system.
  - Dome surface characteristics, reflectivity.
  - Colour space differences, gamma, white point, temperature ....
  - Full fisheye projection vs truncated fisheye.

- Differences arising from the building/dome:
  - Uni-directional vs onmi-direction seating.
  - Dome tilt angle: 0 degrees (planetarium), 30, 45, 90 degrees (upright dome).
  - Height of viewers below the spring line.
  - Degree of seat tilt.
  - Full hemispheres and partial, not all domes are full hemispheres.

  All the above generally determine the natural center of attention on the dome.

- Differences due to imperfections:
  - Degree of edge blending artifacts for multiple projector systems and where they occur on the image.
  - Variation in dome surface quality, for example with inflatable domes.

Contrast, gamma, reflectivity, colour space ...

- Projection system contrast is typically measured as the luminance ratio between pure white and black. Very difficult to judge the importance given that the human visual system can adapt across a very wide range of brightnesses. Contrast ratios as quoted by projector manufacturers generally mean little when applied to fulldome projection
- Note that our visual system is more sensitive to relative brightness differences rather than absolute brightness, as well as having a very non linear response. It is this characteristic that means that relatively low brightness projection systems can be used as long as black out lighting conditions are imposed.
- Dome reflectively. This is probably the most significant factor, cross reflections within a dome and seriously diminish the result (low contrast). A high gain white dome is NOT what you want, compared to desirable high gain flat screens.
- Very difficult to control from a producers point of view because accurate (desired) representation of colour requires a careful calibration of every part of the production process, from rendering, post processing, compositing, to projection.
- In many/most cases the characteristics of any two installations will be different. No real solution while there is no standardisation across installations.
- Note that high contrast projection systems assist in the apparent 3D effects mentioned earlier that can occur in a dome when the surface becomes invisible.

Contrast, gamma, reflectivity, colour space ...

- Colour space refers to the colours that can be represented given a particular projection environment/technology. This also applies to image generation and capture.
- Colour space (enclosed area) from CRT projectors is quite small.
- For DLP there is a tradeoff between colour primary and brightness, the larger the colour space the dimmer the projection. Manufacturers of commodity projectors at least aim for high brightness and therefore poorer colour space.
- The key advantage with laser projectors is the large colour space they can support.
- Accessible parameters: projection system gamma, white point, temperature. Without a fully calibrated production process gamma is the simplest parameter to control. Note also that some projection devices have gamma curves that deviate from a simple power curve, in order to make them more suited to other projection applications.
- Rough starting point is gamma of 2.2 (power law relating pixel values to luminance) and a white point of 6500 Kelvin.
- Bottom line: the technologies to fully utilise or match colours between devices are largely not understood by developers, they are inherently problematic, and the tools not in wide use. End result is most developers fly by the seat of their pants, optimise their content for the intended installation and hope it works OK in others or can be modified (image based) to do so.
- Interesting to consider rendering HDR as a way to maximise the chances of post processing.

Differences between flat screen and fulldome

- Compared to traditional film one needs to move objects around more slowly.
  A consequence of increased immersion.

- Similarly smooth camera movement is important (avoiding hard camera stop/start).

- Light is reflected of the dome surface onto other parts of the dome (not just to the audience as is the case on a flat screen), so very bright areas will tend to lower contrast across the whole dome. The degree to which this is a problem depends on the projection technology and installation.

- Text size and the amount of the dome a single piece of text occupies, difficult to read across a wide field of view. Generally should keep a text token within a narrow enough field of view so that minimal head panning is required.
  Animated text (because it is generally across a larger distance than usual) tends to be more difficult to read in a dome environment.
  Another consideration related to text size is to ensure that text that is legible on a 4K fisheye is also legible on a 1K fisheye, assuming distribution to lower resolution domes is intended.

The horizon

- A problem for traditional horizontally orientated domes.
- Tilting the world leads to a somewhat unnatural experience.
- Tilted domes can represent a correctly orientated horizon.
- Particularly important for directed forward motion and horizontal panning.
- One solution by some practitioners is to render fisheye at greater than 180 degrees.

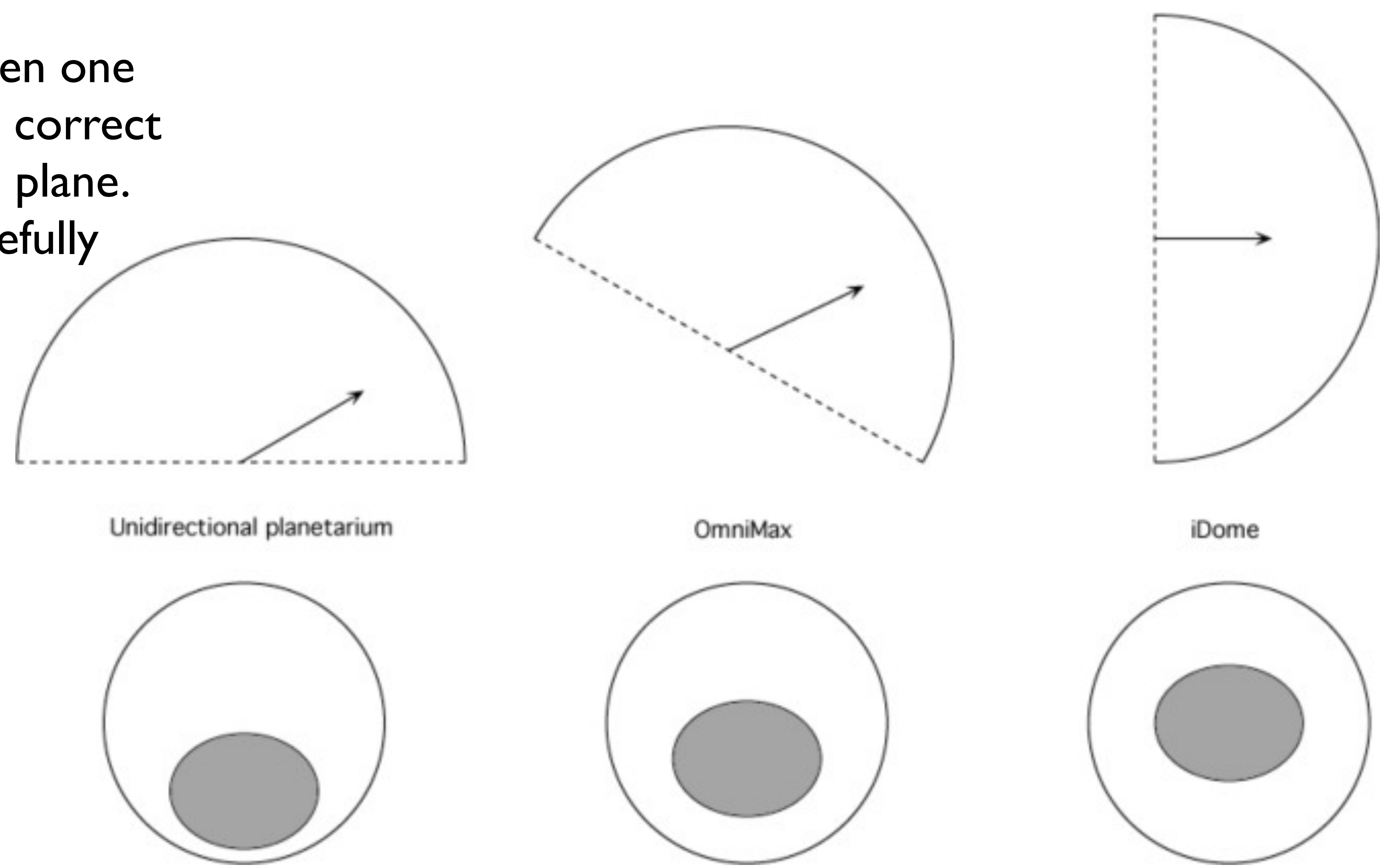
180 degree fisheye

180 degree fisheye tilted 30 degrees

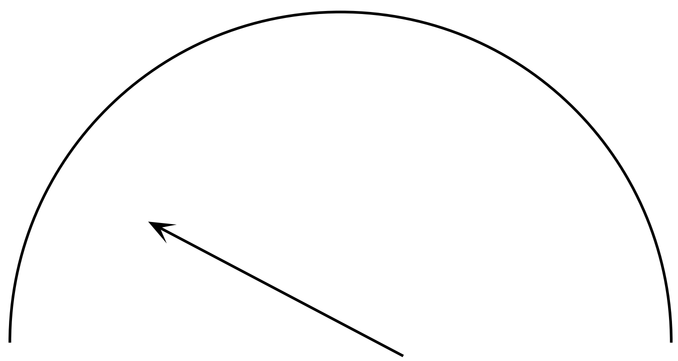
220 degree fisheye

Dome orientation

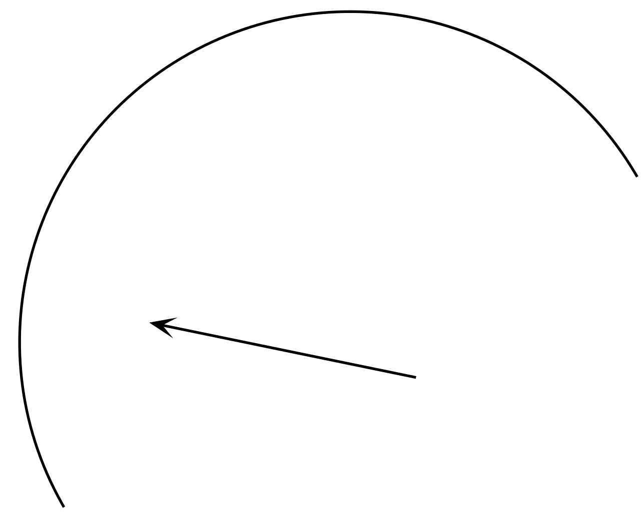
- Orientation:
  - Planetarium: 0 degree orientation.
  - Tilted (eg: iMax): most commonly 30 or 45 degrees.
  - iDome: 90 degrees.
- This does affect the sweet spot for the action for directional seating/viewing.
- Particularly important when one is attempting to present a correct appearing ground/horizon plane. Since the observer is hopefully immersed in the scene, an angled horizon can feel unnatural.
- Content developers want to create material with the widest possible distribution.



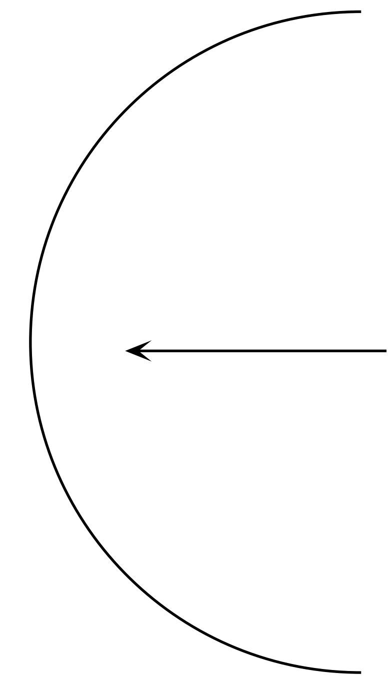
Dome orientation



Unidirectional planetarium



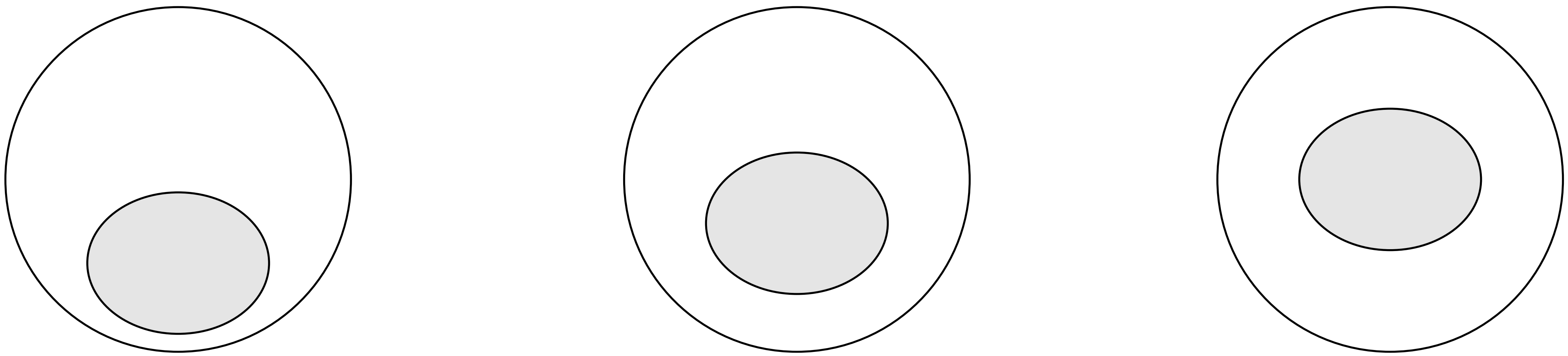
OmniMax (for example)



iDome

Sweet spot

Unidirectional planetarium | OmniMax | iDome



Seating arrangement

- There is only one position for the viewer that results in a perfectly undistorted view of the scene, generally the center of the hemisphere.
- In this position straight lines should appear straight, in all other positions straight lines will appear to curve.
- It is possible to move this correct viewing position to anywhere, outside the scope of this workshop but the technique is generally called "offaxis fisheye".

The curvature in this image is because the camera is located back from the center of the dome. To the seated viewer all the lines look straight.

Seating arrangement

- Omnidirectional.
  This has been the most common arrangement in planetariums arising from their traditional emphasis on astronomy / night sky material.

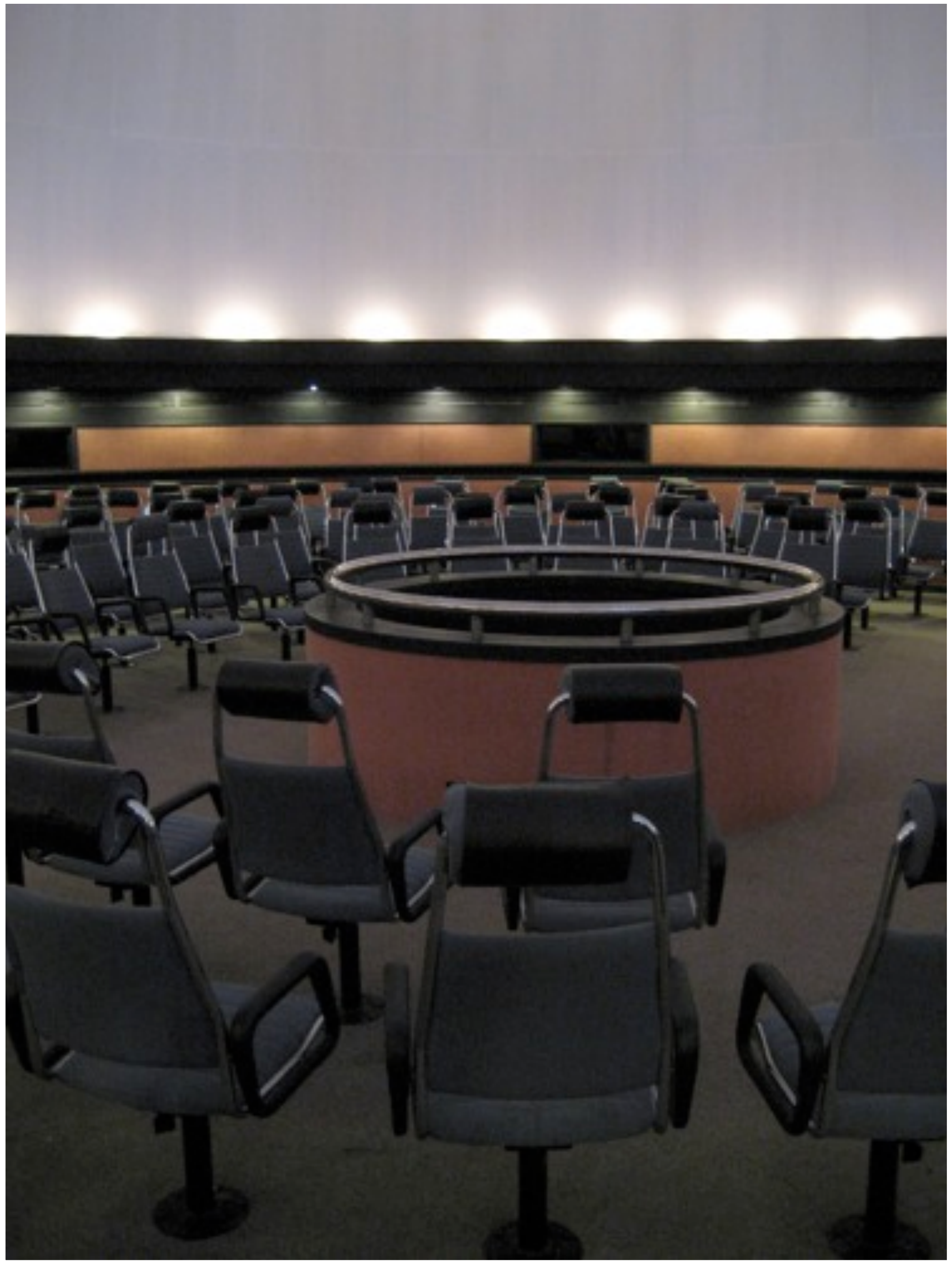
- Unidirectional.
  More common in new planetariums, and in domes designed originally for movie content.

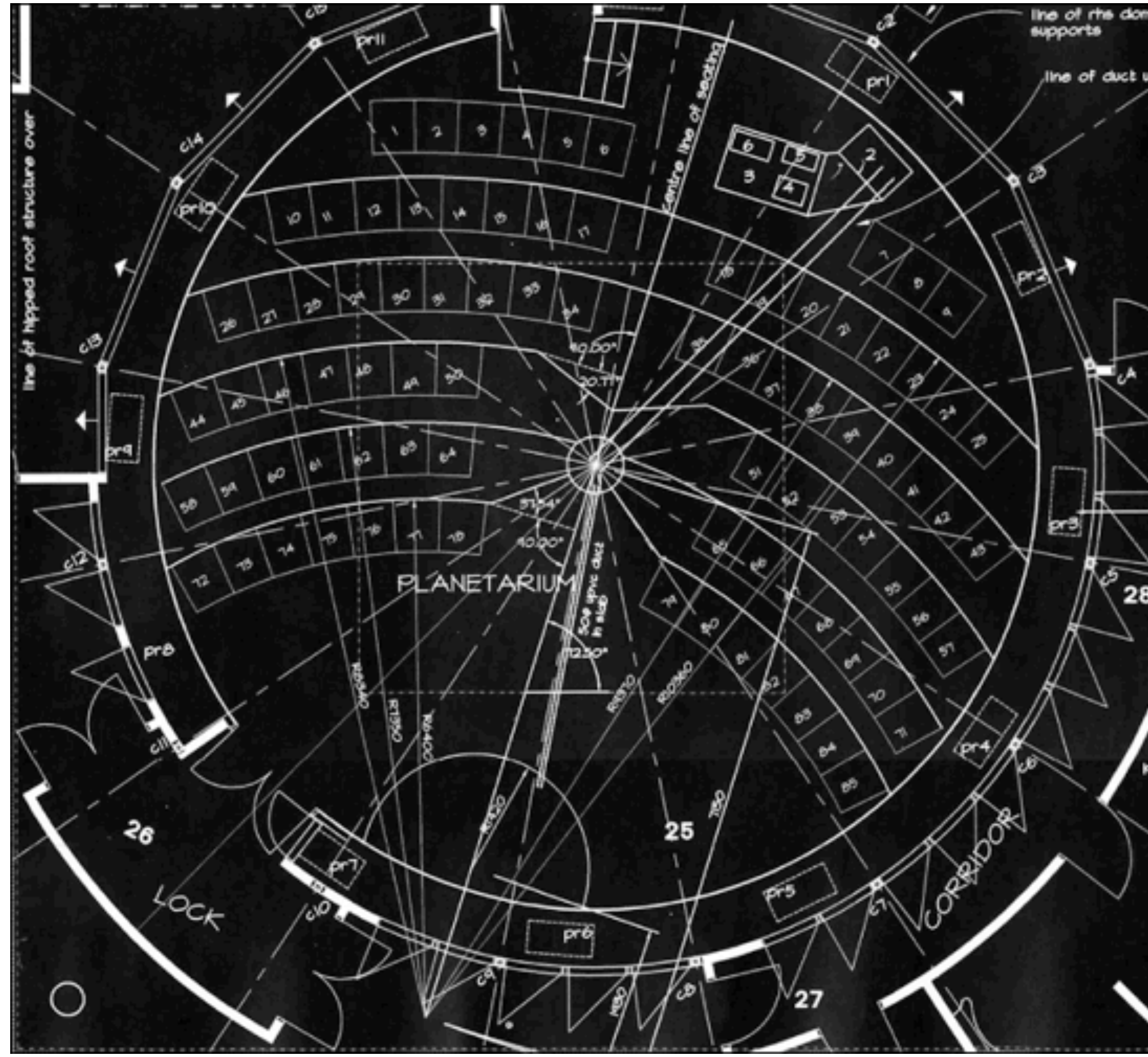
- Omnidirectional planetariums that have been fitted with digital projection can be a challenge for content creators, there needs to be interesting action everywhere.

- Pretty much all fulldome digital content is designed for a centre of attention (sweet spot) forward and 30 to 40 degrees above the spring line.

- Other considerations include the distance from the viewer to the spring line and the degree of tilting in the seating. This determines where the resting direction for the viewers head is.

Seating arrangement





Software

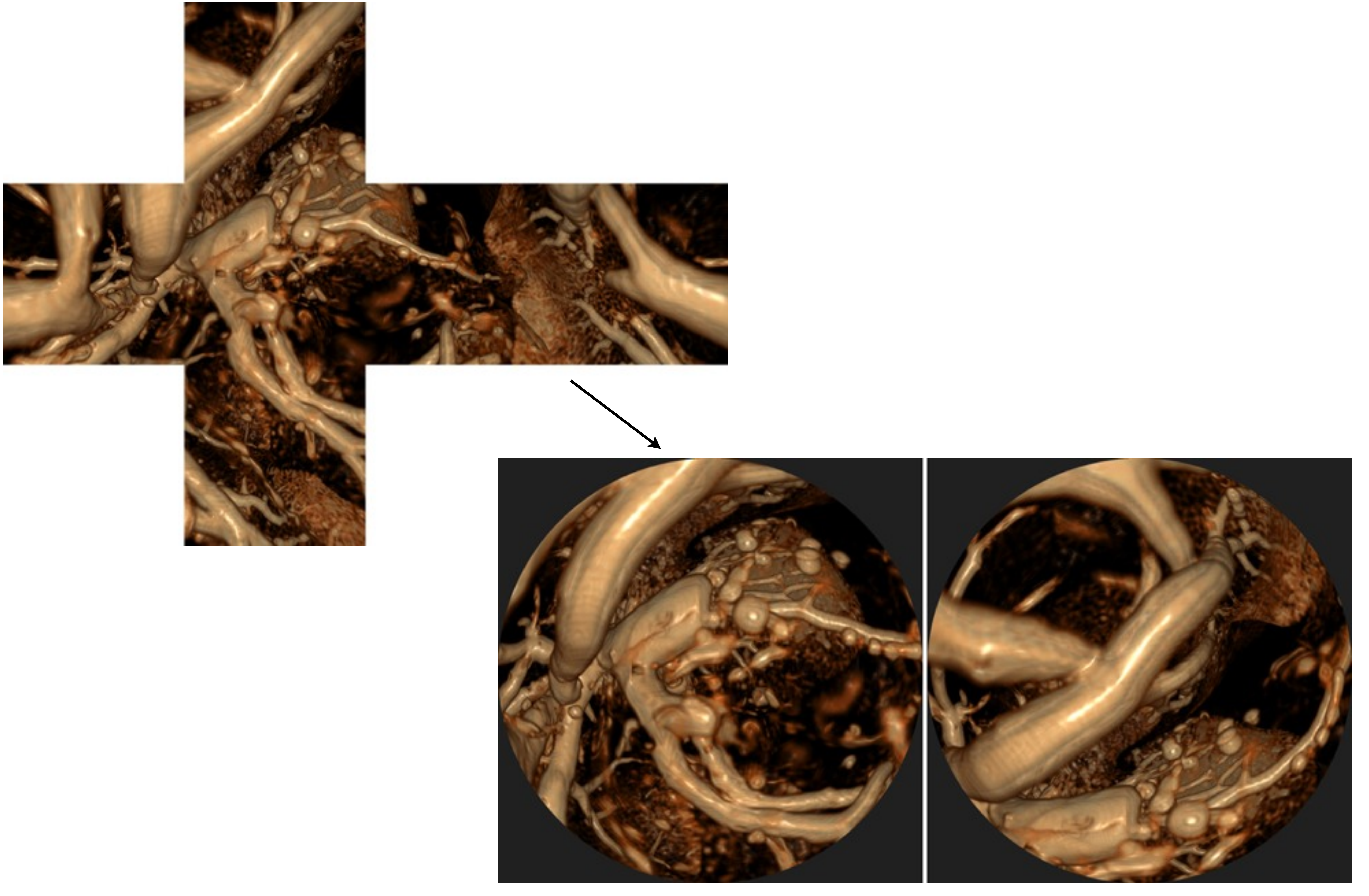
- Fisheye cameras and/or exist plugins for many rendering applications.
- Otherwise image mapping software to convert cubemaps to fisheye.
- Miscellaneous tools to stitch images into fisheye or spherical, convert spherical to fisheye, etc.
- Movie playback software
  - All multi-projector system suppliers have their own proprietary playback software.
  - Single projector systems often can use any movie playback, no warping necessary.
  - warpplayer or Quartz Composer for the spherical mirror systems.
- Show controllers: seamlessly transition between movies.
- Realtime playback software.
  - A number of astronomy packages: Stellarium, Nightshade, Software Bisque, Celestia, etc.
  - Quartz composer.
  - Game engines: Unity, Blender, Crystal quest.
- Each supplier has their own image calibration and edge blending tools.
- Various plugins for compositing.
  - Maps spherical images to fisheye.
  - Maps cube maps to fisheye.
  - Maps planar images to fisheye.

Software: cube2dome

- Unix (eg: Linux, Mac OS-X) command line utility intended to create fisheye frames from a sequence of cube maps.
- Employs a very general file naming convention.
- Allows the fisheye to be orientated in any direction (see -ht and -vt).

```
Usage: cube2dome [options] filemask
       filemask    A C style filename mask, must contain %c then %d for the
                   face name [l,f,r,b,t,d] and frame number. For example:
                      frame_%c_%04d.tga
                   will look for cube faces with one of [l,f,r,b,t,d] substituted
                   for %c and the frame number substituted for %04d (zero padded)
                   New from version 1.06: file mask can now contain two %c fields.
                   This allows frames to be split by directories, for example:
                      sample_%c/frame_%c_%5d.tga
Options
       -w n        sets the output image size to n, default: twice image width
       -a n        sets antialiasing level to n, default: 2
       -n n        starting frame number, default: 0
       -m n        frame number stepping count, default: 1
       -s n        last frame (inclusive and optional)
       -j n        save as jpeg with specific quality (default: TGA, quality 100)
      -bc r g b a  sets the background colour, default: 32 32 32 255
      -mc r g b a  sets the colour for missing faces, default: 0 0 255 255
      -ht n        rotate camera about up vector, default: 0
      -vt n        rotate camera about right vector, default: 0
      -fa n        fisheye angle in degrees, default: 90
      -vp x y z    sets the view position (x,y,z) for offaxis fisheye
       -o s        overlay with the tga file "s" (expects alpha channel)
      -bf n        fade towards the back of the fisheye, n = fadepower
       -d          verbose, debug mode
```

Software: cube2dome

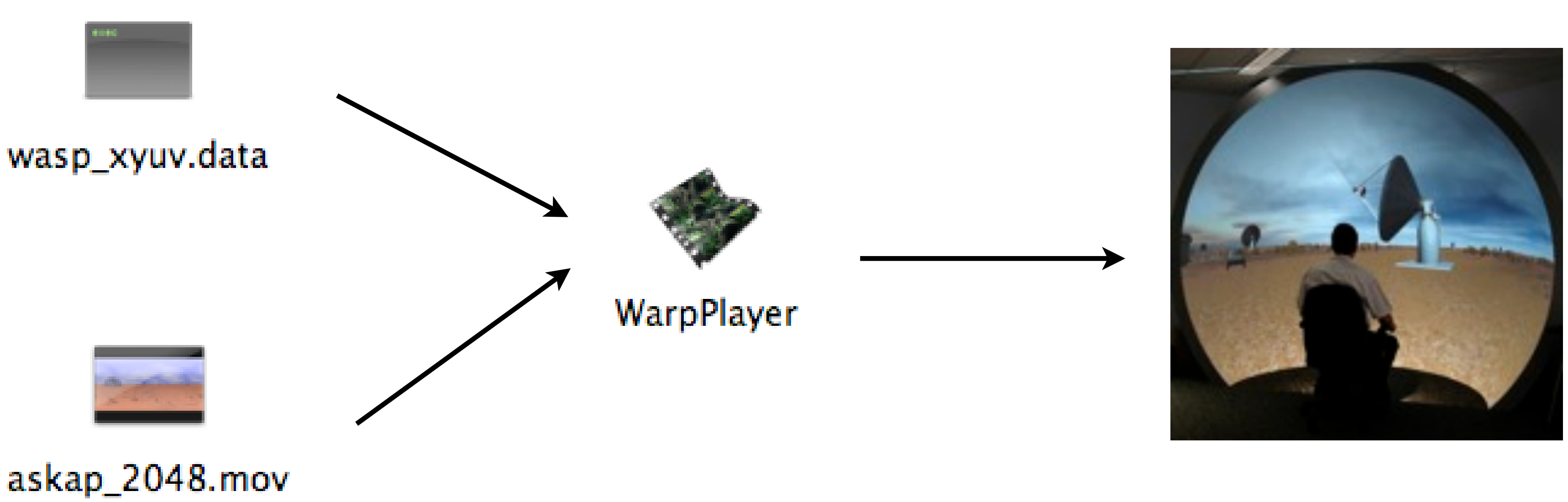


-vt 0

-vt 90

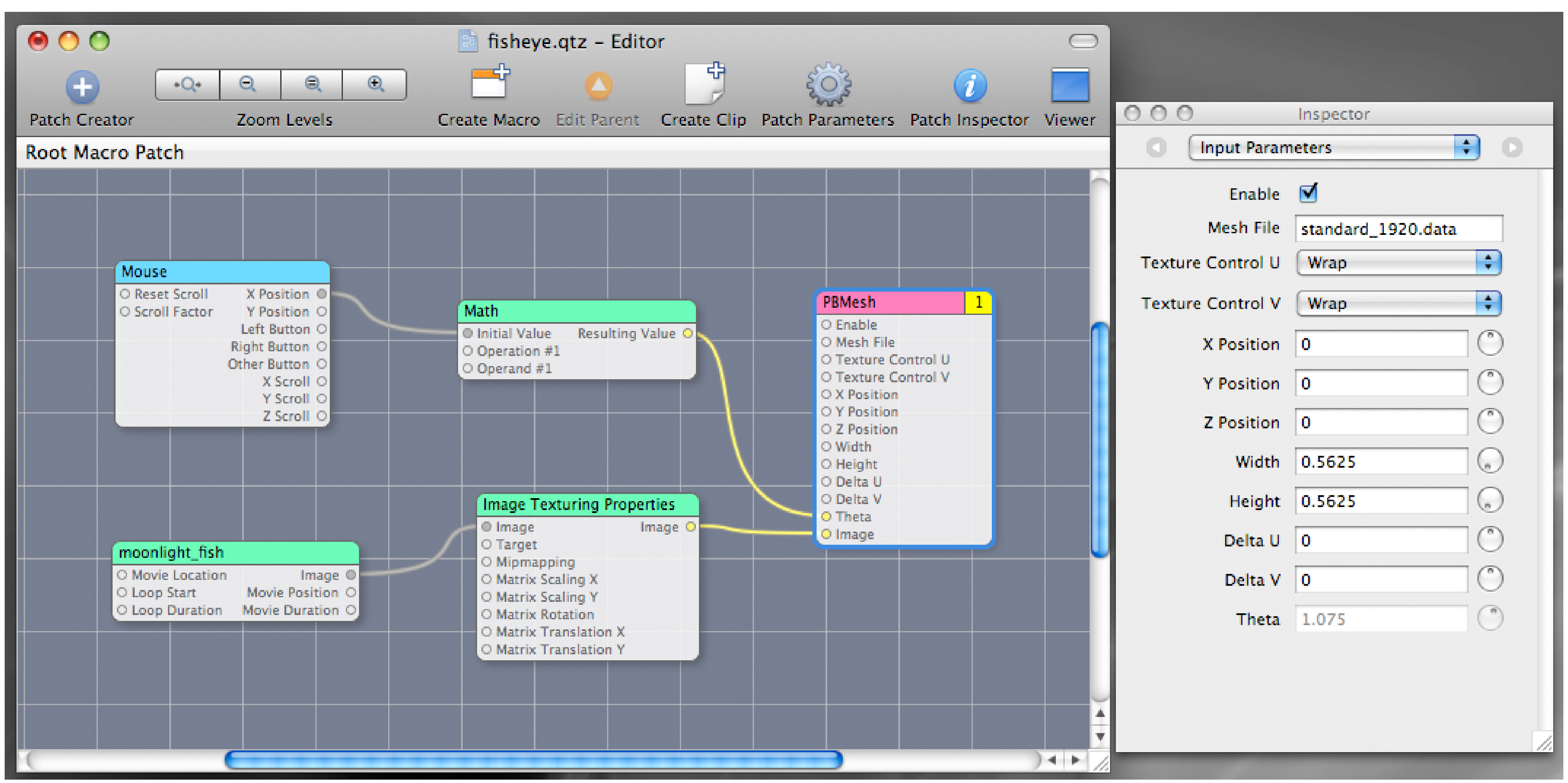
Software: warpplayer

- Takes a movie and a mesh file (looks for "default.data" by default) and plays the movie with each frame applied to the warping mesh.
- Optionally launches fullscreen.
- Totally abstracts the input movie projection type and the output projection type from the application. Contained entirely within the warping file.
- The image type specified in the warp file header only indicates what types of navigation is appropriate.
- Ability to navigate within movie frames, eg: spin a fisheye frame about it's center.
- Geared mainly towards movies consisting of cylindrical or spherical projections, provides horizontal panning.



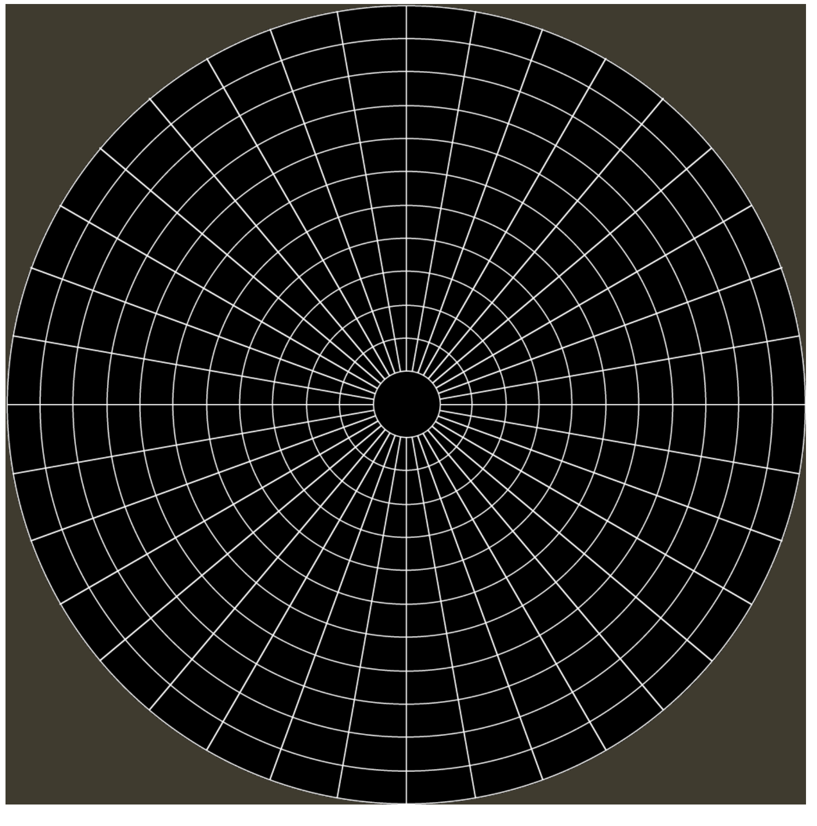
Software: QuartzComposer

- “pbmesh” patch implements warping within Quartz Composer. Available from kineme.net web site.
- Uses the same warp mesh files as warpplayer, (and other tools).
- Ideal for scripting exhibitions with interactive elements, dynamic content, randomised components, transitions, etc.

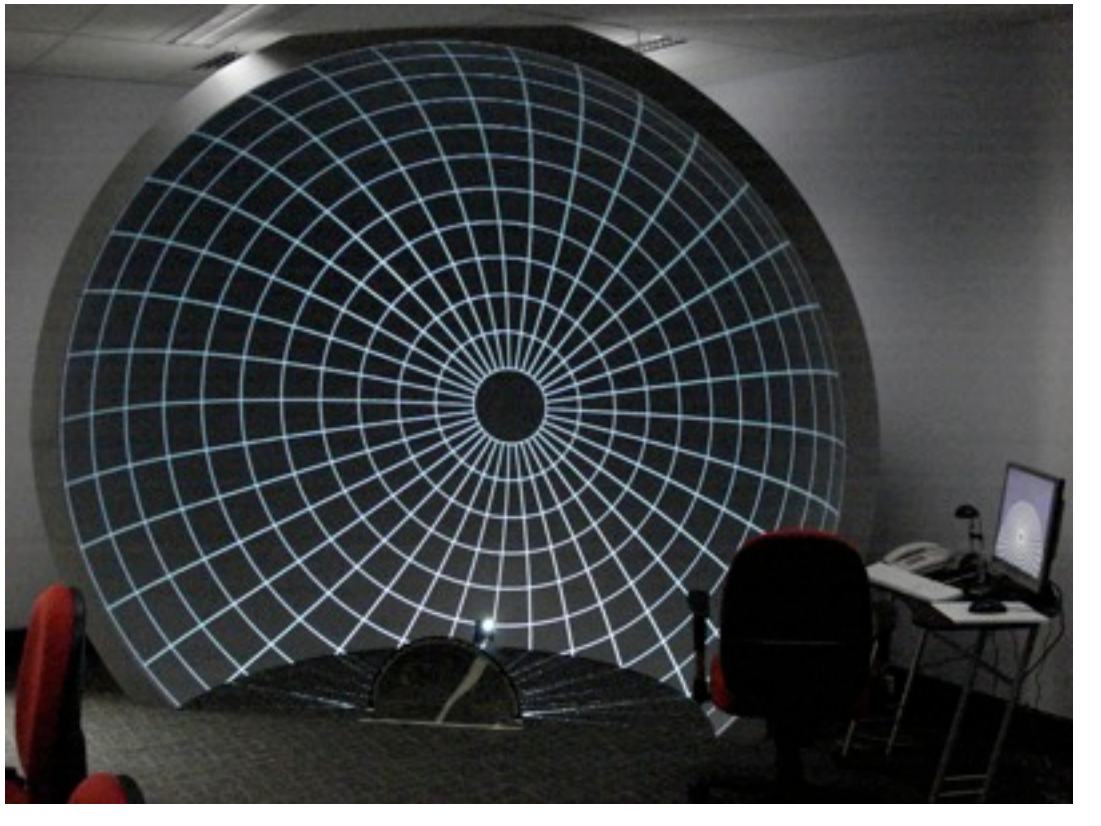


Software: meshmapper

- Given a knowledge of the geometry of the system it creates a warp mesh.
- The user enters the geometric information as best they can and then adjusts the less certain parameters until a test patter looks correct.
- Test pattern is usually a polar grid.
- Parameters includes
  - the position of the components: projector, mirror (dome defines the origin).
  - radius of dome and spherical mirror.
  - optics of the projector: throw, aspect ratio, offset.



Polar grid



Result in the iDome

Software: meshmapper

- Current settings are stored in a file "last.cfg"

```
projector_pos 1.396 0 -1.031
projector_throw 2.85
projector_aspect 1.77778
projector_offset -0.021
projector_angle -0.02
mirror_pos -0.13 0 -1.05
mirror_radius 0.326
dome_radius 1.5
dome_angle 90
dome_flip -1
```

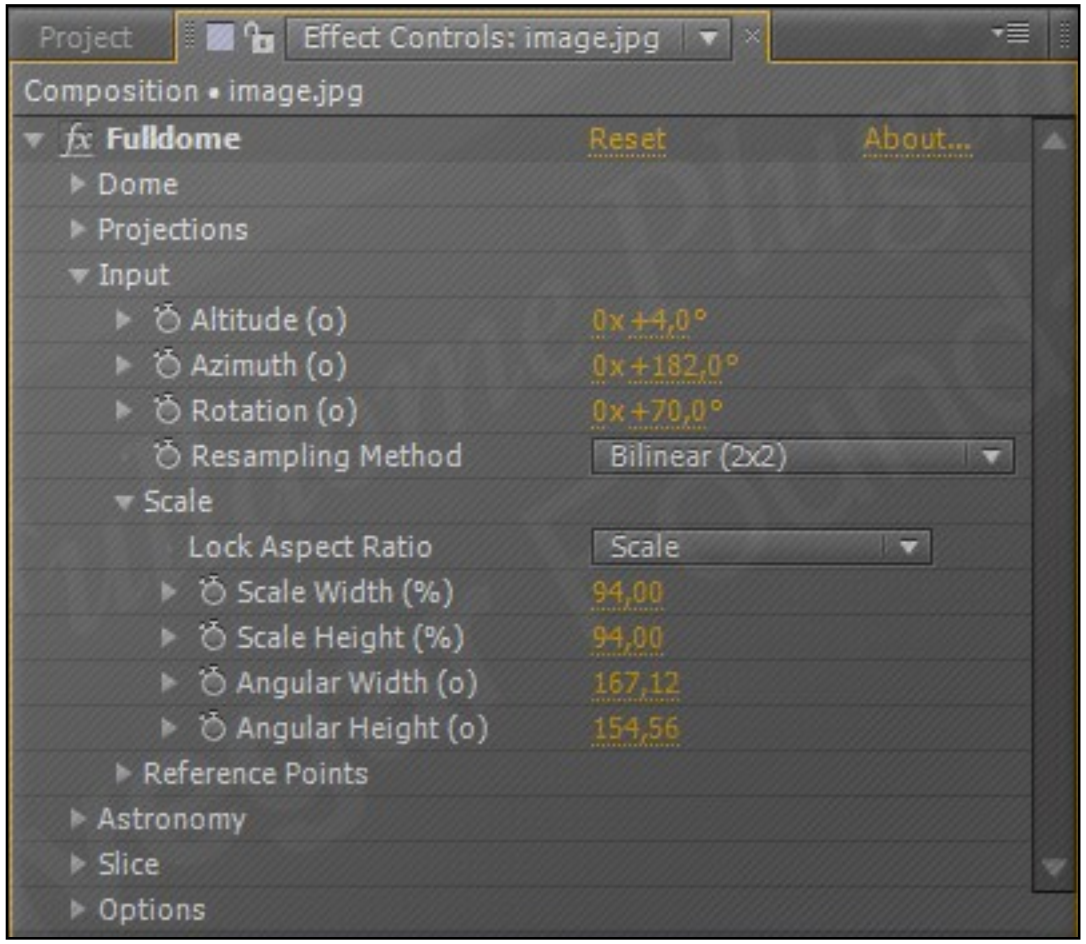
- Keyboard commands allow the user to change the parameters.
- Current settings displays in the top left of screen.

```
Mesh resolution:     142 x 80
Image rotation:      0
Modify:              none

Projector position:  x 1.396
Projector position:  z -1.031
Projector throw:     2.85
Projector aspect:    1.77778
Projector offset:    -0.021
Projector tilt:      -0.02
Projector direction  -1

Mirror position:     x -0.13
Mirror position:     z -1.05
Mirror radius:       0.326

Dome radius:         1.5
Dome tilt:           90
Dome flip:           -1
```

```
Usage: meshmapper [options] tgaimage
Options
                  -h     this text
                  -f     full screen
                  -d     verbose/debug mode
                  -r s   read existing geometry file
Left mouse button for popup menus

Keyboard
         h     camera home
     p,d,m     choose projector, mirror, or dome
   X,Z,x,z     modify position (projector or mirror)
       R,r     modify radius (mirror or dome)
       A,a     modify tilt angle (projector or dome)
       T,t     modify throw (projector)
       O,o     modify offset (projector)
         f     modify dome top (dome)
         w     windowdump
     esc,q     quit
```

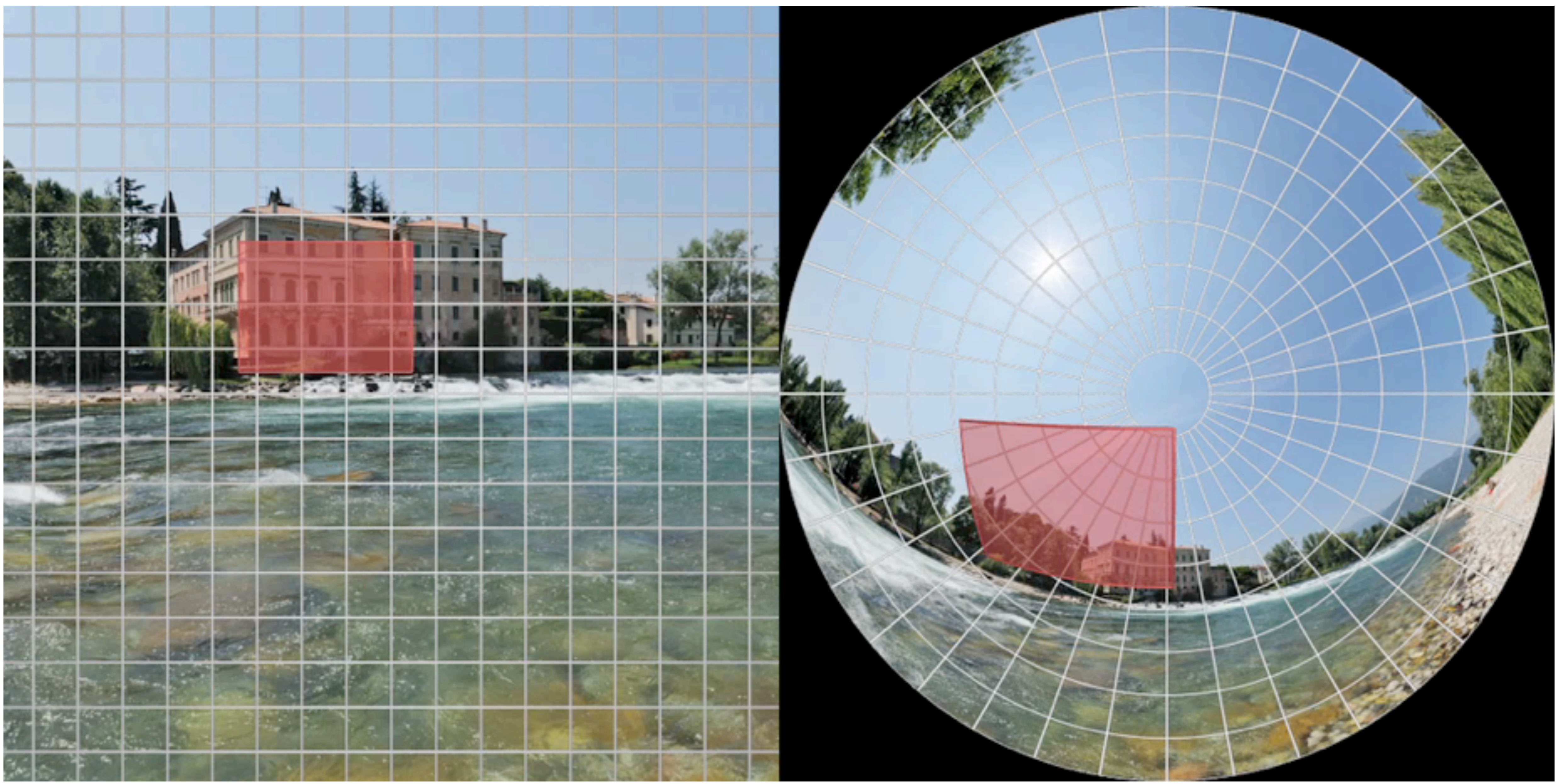
Software: Plugins for After-Effects

- FullDome: Navegar fulldome plugin.
- Domexf: SkySkan fulldome plugin.
- Main application
  - Title and text
  - Planar images -> region of a fisheye
  - Spherical projections -> fisheye
  - Mapping cubic (environment maps)



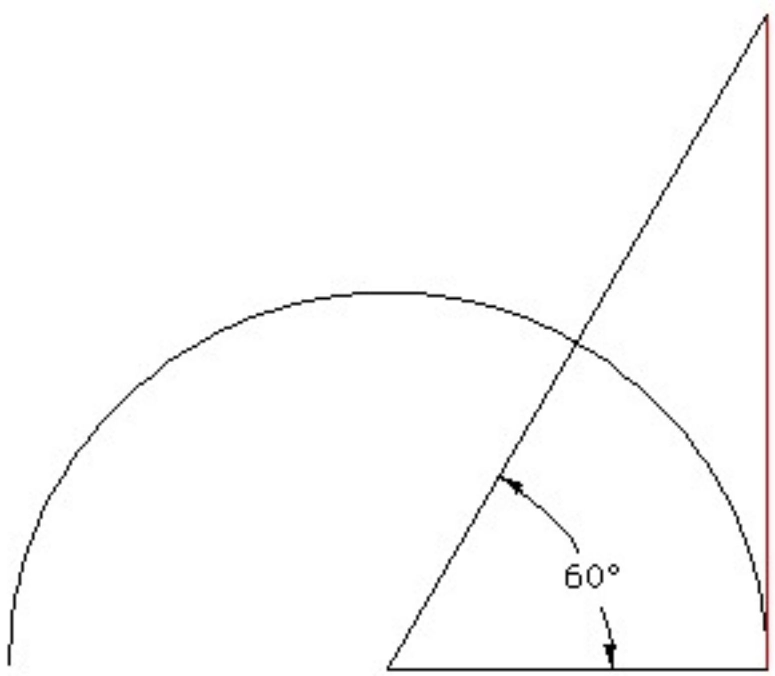
Editing and compositing

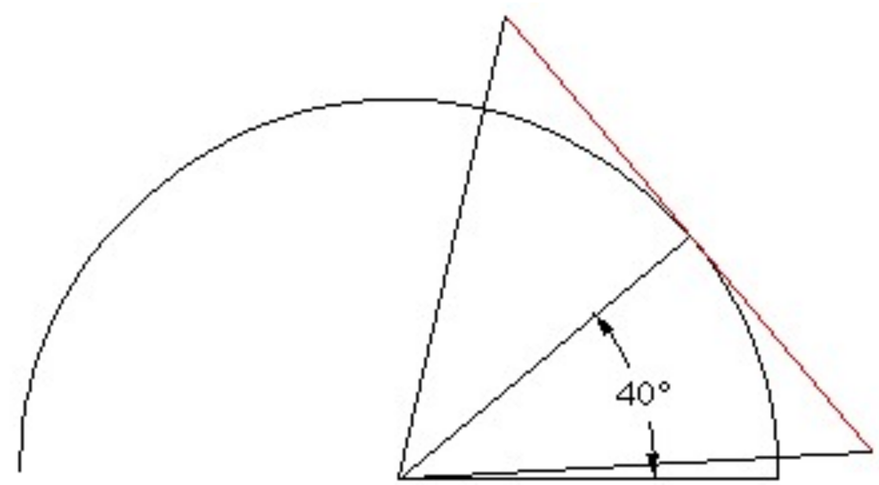
- The "problem" is that it is difficult to use standard compositing packages because the coordinate system for fisheye is very different to the normal rectilinear coordinates of traditional video.
- "Fisheye aware" plugins to various compositing packages are available.

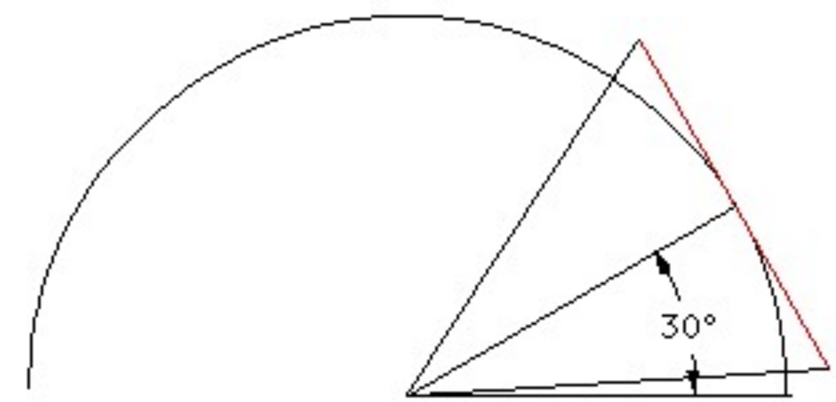


Mapping planar material

- Always think of the image or text on a plane in 3D.
- That plane can be orientated/arranged in lot of different ways.



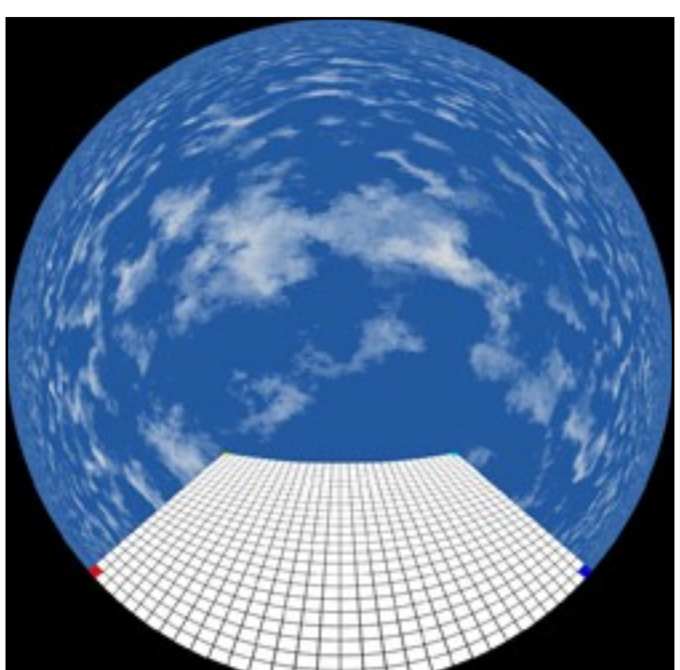


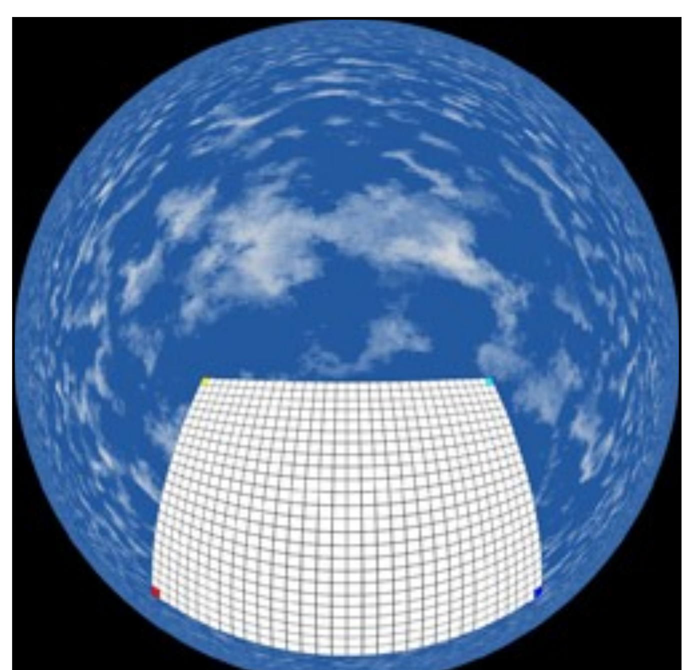


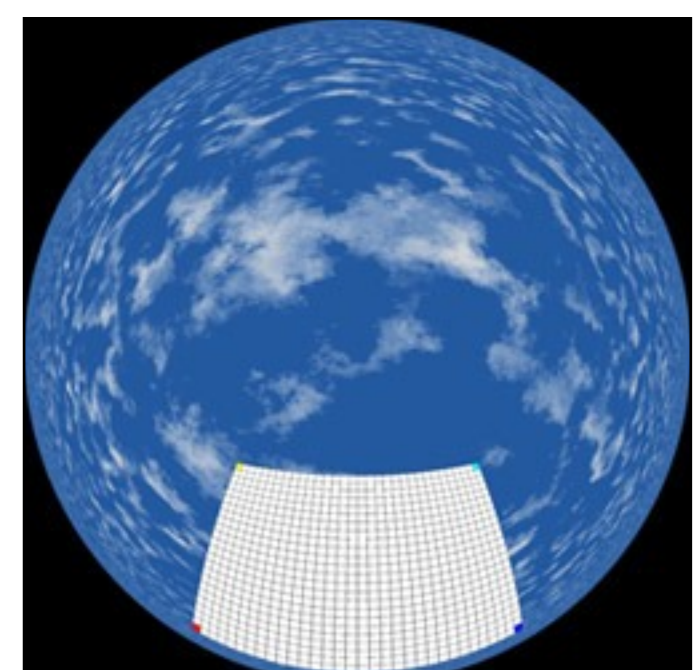
Upright

Rotate by 45 degrees

Rotate by 30 degrees







Online resources

- Yahoo groups
  - fulldome: http://groups.yahoo.com/group/fulldome/
  - small_planetarium: http://tech.groups.yahoo.com/group/small_planetarium/

- DomeFest - International (juried) fulldome festival
  http://www.domefest.com/

- Immersive Cinema Workshops
  http://fulldome.multimeios.pt/

- International Planetarium Society
  http://www.ips-planetarium.org/

- Wikipedia page on fulldome
  http://en.wikipedia.org/wiki/Talk:Fulldome

- Lochness productions

- Spherical mirror FAQ
  http://paulbourke.net/miscellaneous/domemirror/faq.html