

Content Creation for Dome Displays

Part 2 - Technology Workshop

Paul Bourke



3D Printing and Data Visualisation Workshop

28th August 2014

ECU Mt Lawley: Room 13.118
12.15pm - 2.30pm

Presented by IVEC Associate Professor Paul Bourke

Registration Required

eResearch@ECU and IVEC@UWA are pleased to invite you to a **3D Printing and Data Visualisation technology workshop**.

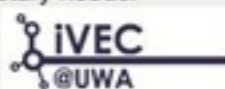
3D printing is an exciting technology whereby a digital representation of data is converted into a physical object that can be held and explored in the same way as we normally study physical objects in everyday life. The technology has been around for some time in the engineering disciplines where it is generally referred to as Rapid Prototyping. Developments in more recent time have removed some of the previous limitations, in turn creating a range of new application areas.

This workshop will demonstrate how 3D printing may be employed as part of the visualisation process, both as a way of studying datasets as well as conveying a sense of that data in teaching and public outreach. Attendees of the workshop will gain an appreciation of the current state of the technology, its strengths and limitations, as well as be equipped to judge when 3D printing may be an appropriate means of visualising data and how to go about creating optimal digital models. A number of examples of the use of 3D printing from researchers in various diverse fields such as medicine, geology, mathematics and archaeology will be presented.

A light lunch will be supplied from 12:15pm, the workshop presentation will start at 12:30, followed by a question and answer session from 1:30pm.

This workshop is free of charge, however prior registration is essential.

To register, or for further information, please contact Donna Antulov at d.antulov@ecu.edu.au. When registering, please advise of any special dietary needs.



Automated 3D Model – Reconstruction from Photographs

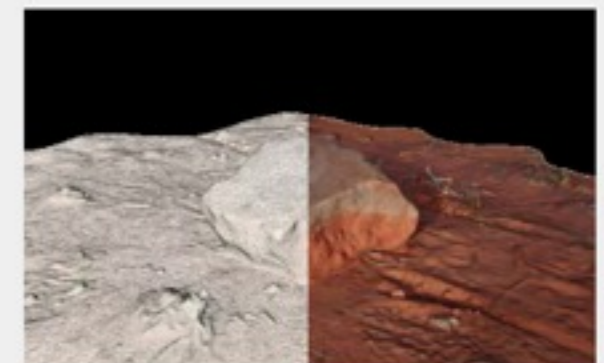
2 September 2014

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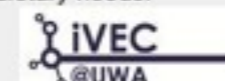
Photogrammetry is the traditional name given to the derivation of some 3D quantity derived solely on the basis of a collection of photographs. In recent years this has been an intensive area of research and the quality of the algorithms is reflected in this effort. The state of the art is currently that one can create reasonable quality 3D models from a collection of photographs without a significant amount of domain knowledge, specialist hardware and software, or with the need to place markers in the scene or follow rigorous calibration procedures.

This workshop will aim to provide attendees with a complete introduction to the subject matter with an emphasis towards 3D capture of heritage objects as the topic for most examples. The workshop will discuss the theory, introduce current software solutions/ pipelines, make reference to camera and techniques that result in an optimal chance of successful reconstructions, and present some of the post processing requirements and tools. Attendees will gain awareness to key concepts, familiarity with relevant software tools, realistic expectations and limitations, knowledge of applications and research where 3D reconstruction is being employed. At the end of the workshop attendees should feel confident in applying and experimenting with this exciting new technology.

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Contents

- Cover to four technologies
 - Canon 5D and fisheye lens
 - Fisheye stills
 - Fisheye movies
 - 360x180 spherical navigable images
 - Red Scarlet
 - Fisheye movies
 - LadyBug cameras
 - Spherical navigable movies (Also potentially cylindrical and fisheye)
 - Unity3D
 - Interactive environments
- Not covered but happy to discuss general computer graphics content and rendering.
- Informal discussion
 - hands-on with equipment
 - more in-depth exploration depending on interest
 - opportunity to create and process content using the above hardware

These slides will be made available online, <http://paulbourke.net/papers/HIVE2/>
All the demonstration material on USB stick if you want a copy now.

Assumptions

- Will assume familiarity with material covered in part 1.
See <http://paulbourke.net/papers/HIVE/>
- In particular
 - the concept of projections: planar, fisheye, cylindrical, spherical.
 - relationship between person/dome and camera/fisheye.
 - relationship between lens image and sensor region.
 - implications of producing content for different dome orientations.
 - how fisheye is warped in order to create the correct image on the dome surface.
- Will present particular workflows based upon Photoshop and AfterEffects, there are obviously others.
- If you understand the principles presented here you should be able to apply them to other software capable of the same functionality.
- Won't go into all details of a particular piece of software, will try to focus on just those aspects directly related to dome production.
- Lots of hardware and software involved, will be surprised if it all runs smoothly.
- Lots of hardware and software involved, will be surprised if I haven't forgotten to bring something.

Canon 5D Mk III and fisheye lens: Stills

- Canon 8-15mm zoom lens - unusual to have a zoom fisheye.
- For other combinations (SLR and fisheye lens) be aware of the fisheye coverage on the camera sensor.
- Trade off between the portion of the fisheye captured and the resolution.
- Preparation in Photoshop: determining fisheye circle, cropping to square image.
- Canon 5D Mk III and Canon 8-15mm zoom lens, zoomed all the way out results in about a 3700 square fisheye.
- Fisheye lenses usually have quite good depth of focus.
- Some like the Sunex don't even provide a focus capability.



Zoomed out

Canon 5D Mk III and fisheye lens: Stills

- Given the truncation on the dome in the HIVE, higher resolution can be achieved by zooming in.
- However effective resolution of the HIVE system is already lower than the full frame fisheye.
- Capturing truncated fisheye content also limits the use of the material for other domes that may not be truncated. iDome, Scitech, etc.
- If truncated fisheye is used then the final imagery still needs to be presented as a square fisheye frame, letter boxed. All hemispherical dome environments will have a playback system that will expect full fisheye.
- Dome projection tools are going to expect full fisheye.



Partially zoomed in

Canon 5D Mk III and fisheye lens: Stills

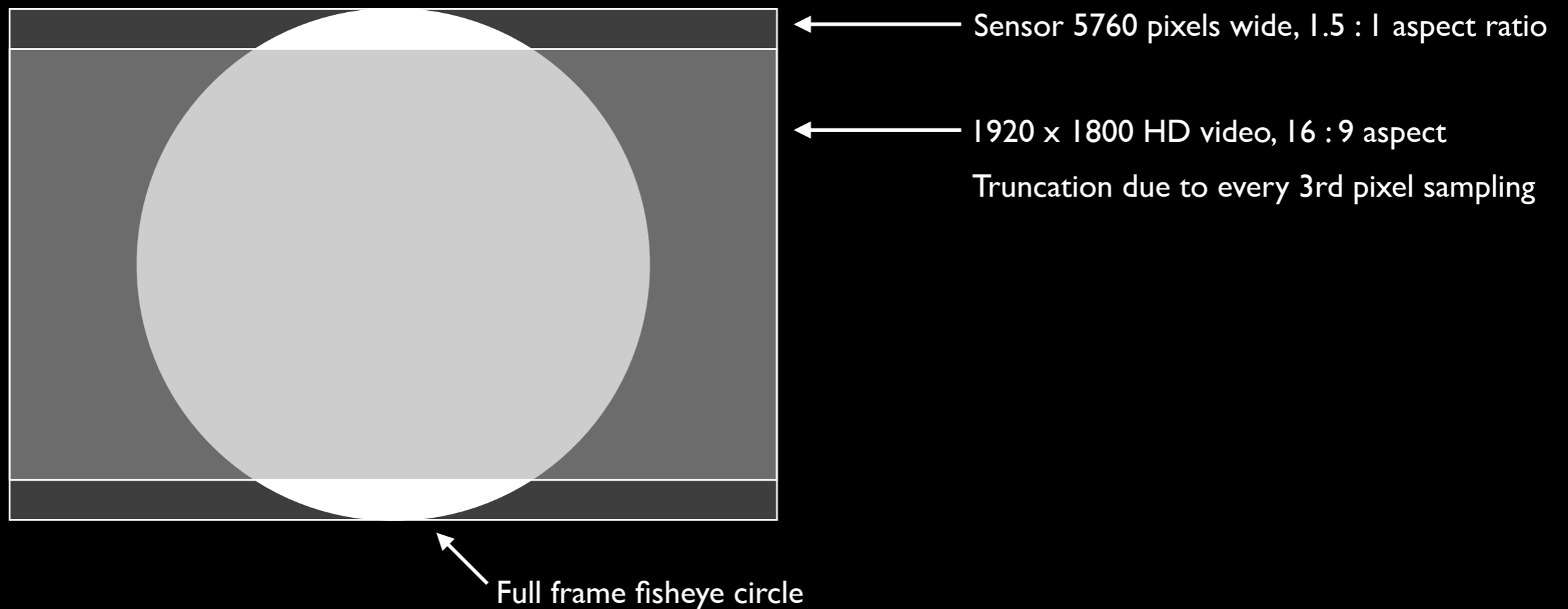
- Worked examples.
- 5760 x 3840 (1.5 aspect ratio) 22 MPixels.
- Example 1: Photoshop cropping. Approximately 3660 fisheye circle.
- Example 2: Photoshop letter boxing. Approximately 4940 fisheye circle.



Final letter boxed fisheye

Canon 5D Mk III and fisheye lens: Movies

- A smaller portion of the sensor is used in movie mode, characteristic of many SLR cameras.
- One could use a lens designed for an APS-C sensor to give a full fisheye circle but the fisheye resolution will be rather low.
- The HIVE dome is conveniently already truncated by more than the zoomed out truncation of the camera and lens demonstrated here.
- See later for a APS-C sensor and APS-C designed fisheye lens on the Red Scarlet.



Canon 5D Mk III and fisheye lens: Movies

- Pipeline.
- Movies off the compact flash card in QuickTime format H264 codec 25 fps for PAL, 29.97 for NTSC. Most dome content is 30fps.
- Preparation in After Effects: determining fisheye circle, cropping to square aspect ratio movie.
- Process fisheye movie frames in the same way as used Photoshop to process individual images.
- Maximum resolution for the HIVE dome by finding the vertical truncation that matches the dome truncation.



1230 fisheye circle



1600 fisheye circle

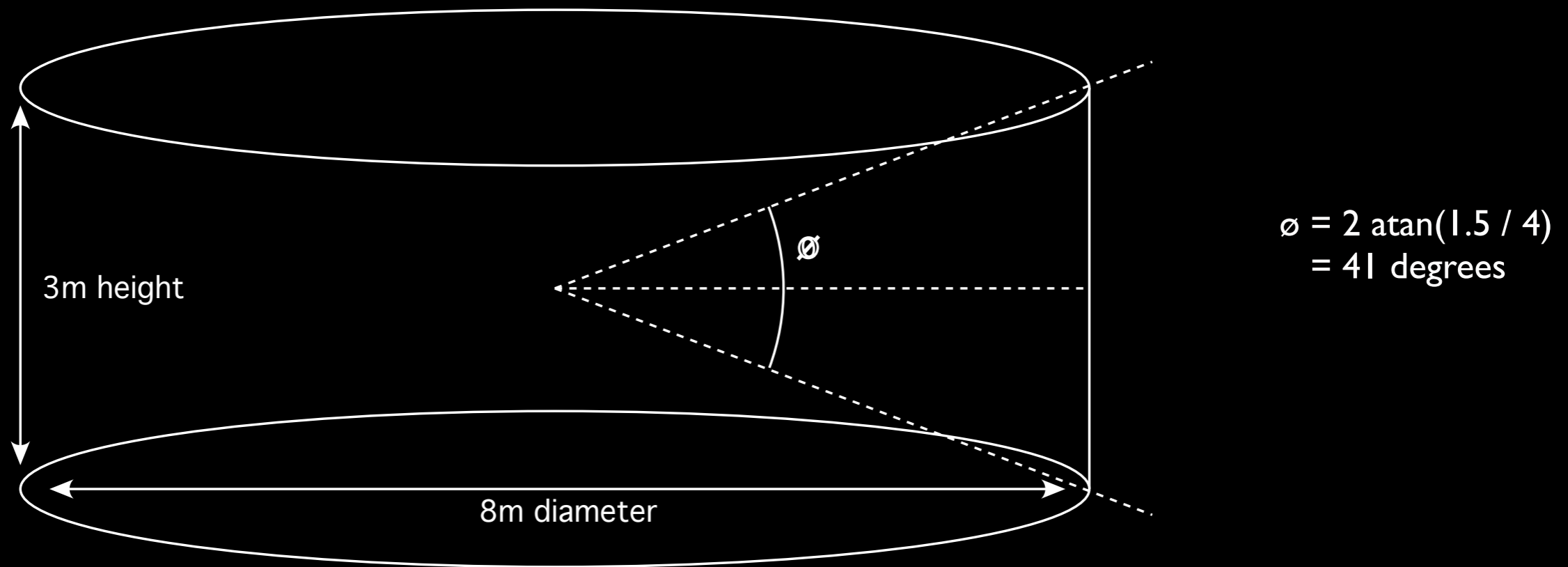
Canon 5D Mk III and fisheye lens: Movies

- Worked example in After Effects.
- Set project dimensions, import QT movies, colour adjust export.



Canon 5D Mk III and fisheye lens: Movies

- Creating panorama movies for the cylindrical display.
- A fisheye captures 180 degrees horizontally so can also be used to create a 180 degree panorama movie.
- This would not be stereo, stereoscopic cylindrical movies are another story, outside the scope of this presentation but happy to discuss later.
- Could also be used to create movies for the wedge walls.
- Underlying principle is that if sufficient visual field is captured for a particular display then the correct projections can be derived irrespective of the display geometry. Just pixel shuffling.



Canon 5D Mk III and fisheye lens: Movies

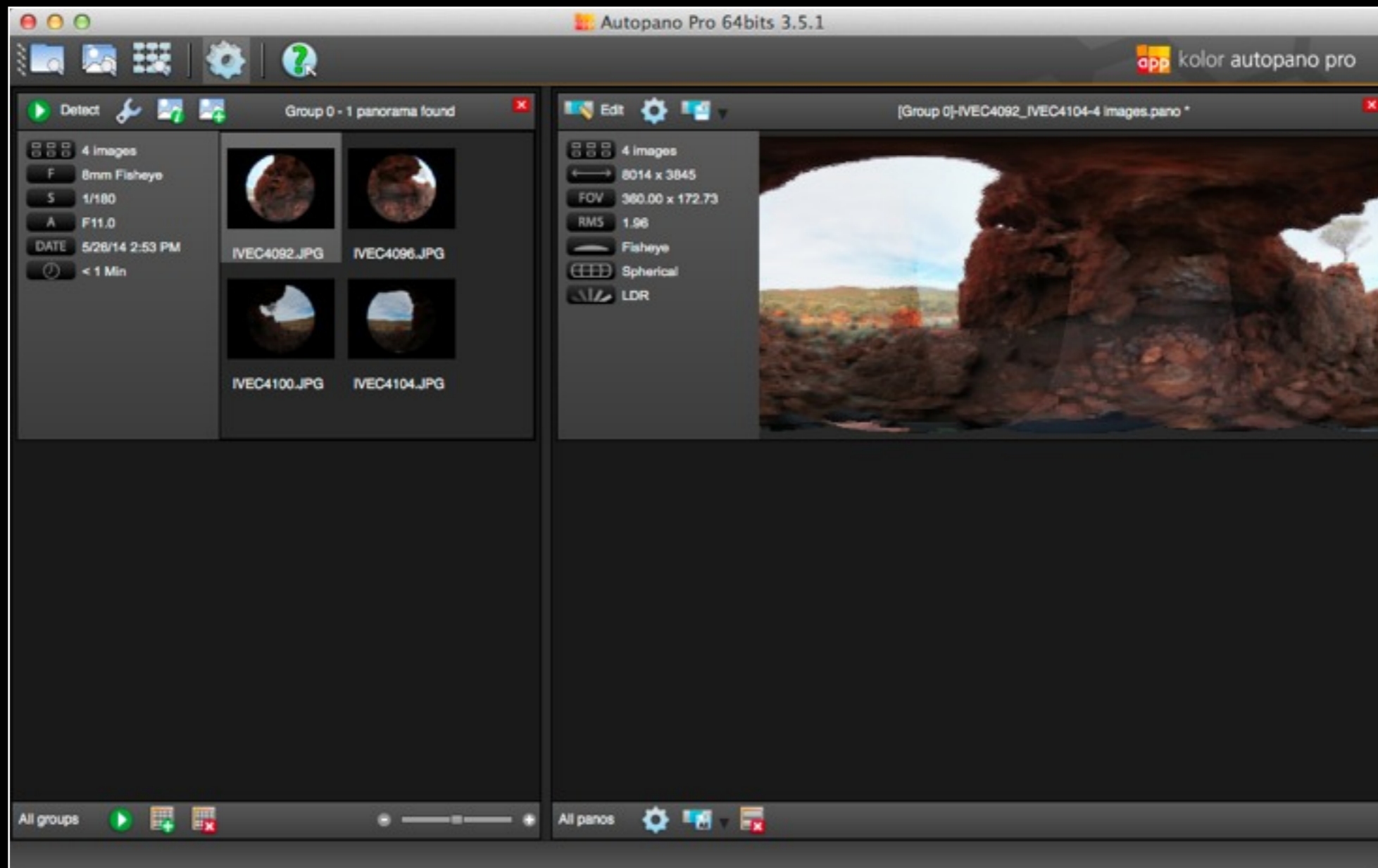
- Process
 - Export frames and audio (QuickTime Pro for example).
 - Optionally crop images horizontally to fisheye circle (GraphicConverter for example).
 - Extract cylindrical portion with the correct vertical FOV (frontfish2pano for example).
 - Rebuild into movie of format/codec of choice (AfterEffects for example).
 - Re-attach audio channel (AfterEffects for example).
- Would normally zoom fisheye to the whole 1920 pixels wide since only a small portion of the vertical extent will be used.
- Creates almost 2K cylindrical movies.
- See later in Red Scarlet discussion for higher resolution (4K) cylindrical movies.
- Any image remappings like this must use high levels of antialiasing, my tools just use supersampling antialiasing, typically 3x3.
- `frontfish2pano -w 2000 -a 3 -ap 41 export%03d.tga`



180 degrees horizontally by 41 degrees vertically

Canon 5D Mk III and fisheye lens: Spherical

- 360x180 spherical and navigable images.
- Key to all well stitched panoramic content is being able to rotate the camera about nodal point.
- Will use the Nodal Ninja mount here, there are others.
- Stitching with AutoPano Pro.



Canon 5D Mk III and fisheye lens: Spherical

- In this case 4 images taken in 90 degree steps. Can also zoom and use rotated camera for higher resolution. Obviously need a tripod with angle marks or a notched mount.
- Also possible to just use 3 images at 120 degree steps for higher resolution.



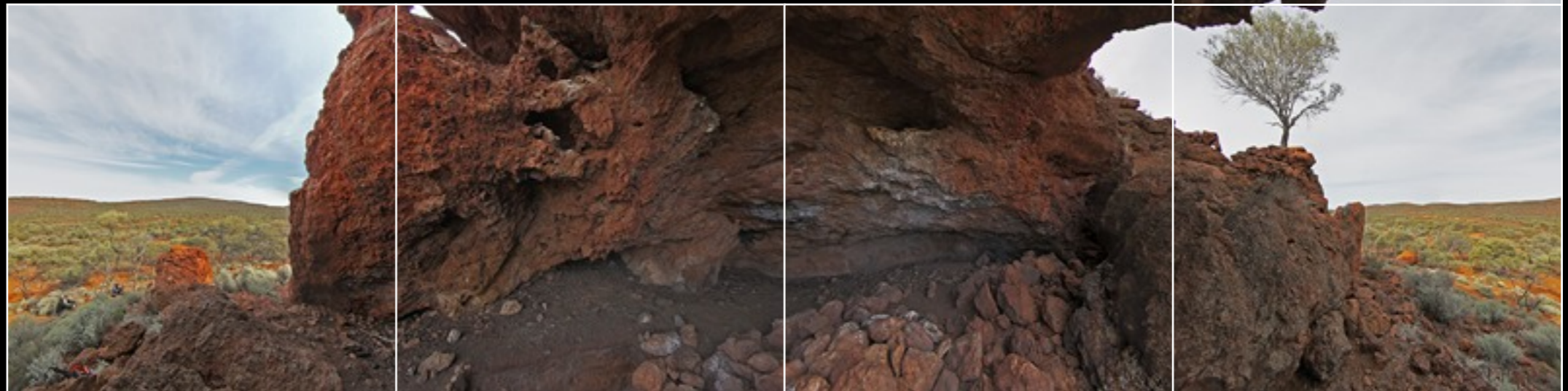
Canon 5D Mk III and fisheye lens: Spherical

- Resulting panorama should have a 2:1 aspect (360 degrees by 180 degrees).
- Tilted panorama head should give perfect stitch at the north pole.
- ~ 8K wide, 16 bit colour.
Higher colour depth due to double images over the blend zones and using raw images.
- Do colour grading at this point.
- How to edit south pole? Cannot do it in spherical coordinates.



Canon 5D Mk III and fisheye lens: Spherical

- Map to cube faces, each a 90 x 90 degree perspective projection.
- I use my own tools but there are other options. e.g.: as part of krpano
`sphere2cube -w 2048 -a 2 pano.tga`
- Edit the south pole and map back to spherical.
`cube2sphere -w 8192 -a 2 %c_pano.tga`
- Clone tool or content aware fill.



- Also the time to do any photographer/tripod shadow removal.
- Result largely depends on the skill of the operator and time spent.



Canon 5D Mk III and fisheye lens: Spherical

- Worked example.
- I will use command line tools but there are other options.



Red Scarlet: Fisheye movies

- .R3D files, proprietary RED format.
- Records raw data from sensor, allow for maximum scope for adjustments in post production.
- Wavelet based hence allows fast multi resolution processing and preview.
- Like most high resolution video cameras there is a tradeoff between resolution, framerate and compression ratio.
- Largely limited by bandwidth from sensor to storage device.
- For example with the current Red Scarlet some options are given in the table below.
(Multitude of other combinations)
- The higher the (lossy) compression ratio the greater the possible frame degradation.

Resolution	Maximum framerate	Compression
4196 x 2180	30 fps	8 : 1
4196 x 2180	25 fps	6 : 1
3072 x 1620	48 fps	7 : 1
3072 x 1620	29.97 fps	4 : 1
2048 x 1080	60 fps	4 : 1

Red Scarlet: Fisheye movies

- Sigma 4.5mm, Sunex 5.6mm (185 degrees), and Sigma 8mm all have APS-C size sensors.
- Need to consider lens and sensor size.
- The area of the sensor used and hence degree of clipping also depends on the resolution setting.
- Example: Sigma 4.5mm fisheye, and a 4K recording the final fisheye resolution is 2330 square.



Red Scarlet: Fisheye movies

- Example: Sigma 4.5mm fisheye, and a 3K recording the final fisheye resolution is (also) 2330 square.
- Same resolution because unlike the Canon, the Red samples at 1:1 and the fisheye (no zoom on the Sigma) is the same size on the sensor. Crops rather than subsamples the sensor.
- Higher frame rates and lower compression possible for the same pixel resolution.



Red Scarlet: Fisheye movies

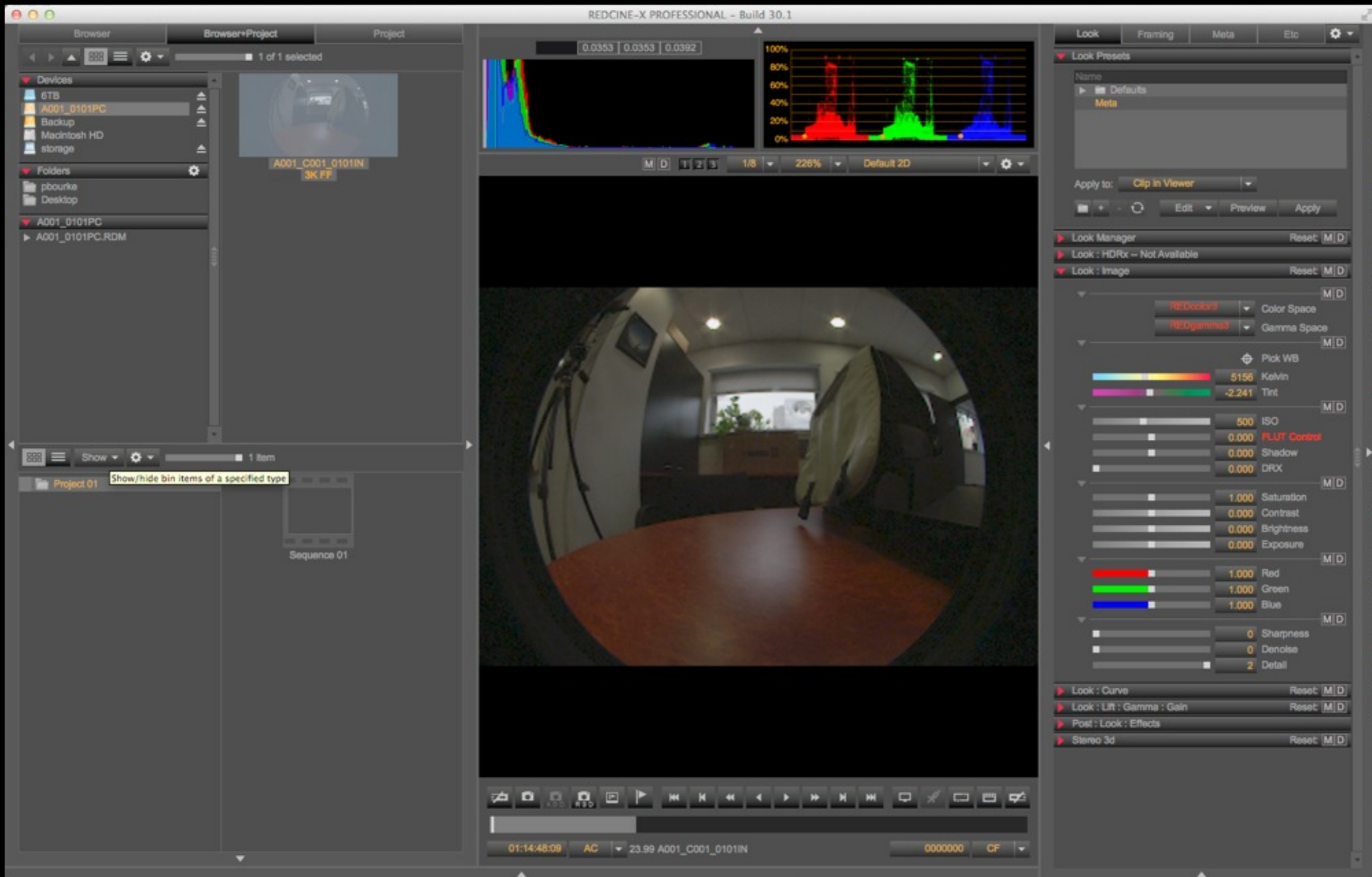
- Example: Sigma 4.5mm fisheye, and a 5K recording the final fisheye resolution is (also) 2330 square.
- This would have lower frame rates on the Scarlet, the other higher end cameras in the Red family allow for full frame rate recording at this resolution.
- Full fisheye ... APS-C sensor and APS-C lens.



Red Scarlet: Fisheye movies

- Two (at least) pipelines
 - Install .r3d codec and then use something like After Effects.
 - Use their Redcine-X Pro application for image processing and export.
[Expects high pixel count screen]
- Both free downloads from the Red web site.
<https://support.red.com/home/>
- Support provided initially for Apple but now also Windows.
- Final format for fisheye, irrespective of the source is square fisheye frames with 180 degree vertical and horizontal field of views.
- Letter boxing required to expand the frame to full inscribed circle in square frame. 1:1 pixel aspect.

Red Scarlet: Redcine-X Pro



Red Scarlet: AfterEffects

- Worked example.



Red Scarlet: Cylindrical movies

- Same discussion applies as for the Canon fisheye movies, can also create content for the cylinder.
- Only difference is a higher resolution result. 4-5K horizontally.
- Benefit here (higher resolution) using the Canon full frame fisheye since we only need 41 degree vertically. Maximise sensor width.



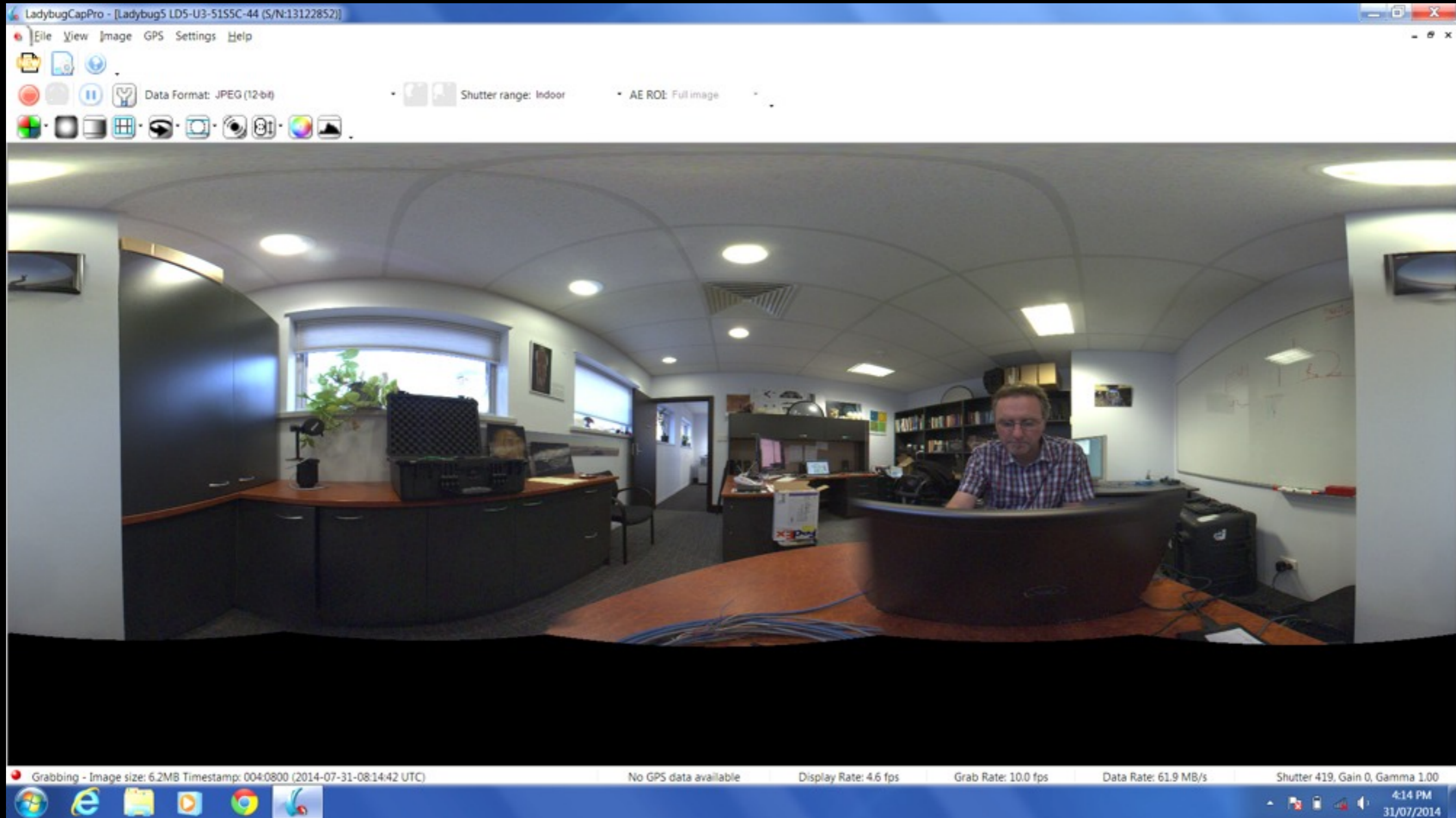
180 degrees horizontally by 41 degrees vertically

LadyBug camera

- We have the LadyBug-3 and LadyBug-5, will discuss the later here.
- Suitable for filming for the iDome and the cylinder.
Since both are 360 degrees horizontally, this offers the opportunity for navigable video.
- LadyBug-5 can mimic the resolution and frame rate of the LadyBug-3.
- LB2 and LB3 based on Firewire 800, LB5 based upon USB-3 (but custom drivers).
- Bottom line is how close the nodal points of each camera can be.
- LadyBug series a tradeoff between resolution and frame rate
 - LadyBug-2: 30fps, 3600x1800 pixels
 - LadyBug-3: 16fps, 5400x2700 pixels
 - LadyBug-5: 10fps, 8000x4000 pixels
- Each camera is 2048x2448 pixels.
- Can export raw frames or stitched images.
- Camera records to proprietary .pgr files (Point Grey Research).
- A large number of record modes and settings.
- Does not record audio.
- Other options include multiple GoPro camera rigs, even multiple SLR camera rigs.

LadyBug camera

- Same software used to capture as export: LadyBugCapPro.
- Only available for MS Windows.



LadyBug camera

- Export frames in a number of formats and projections.
- Will use spherical here since the most general, they call it “panorama”.

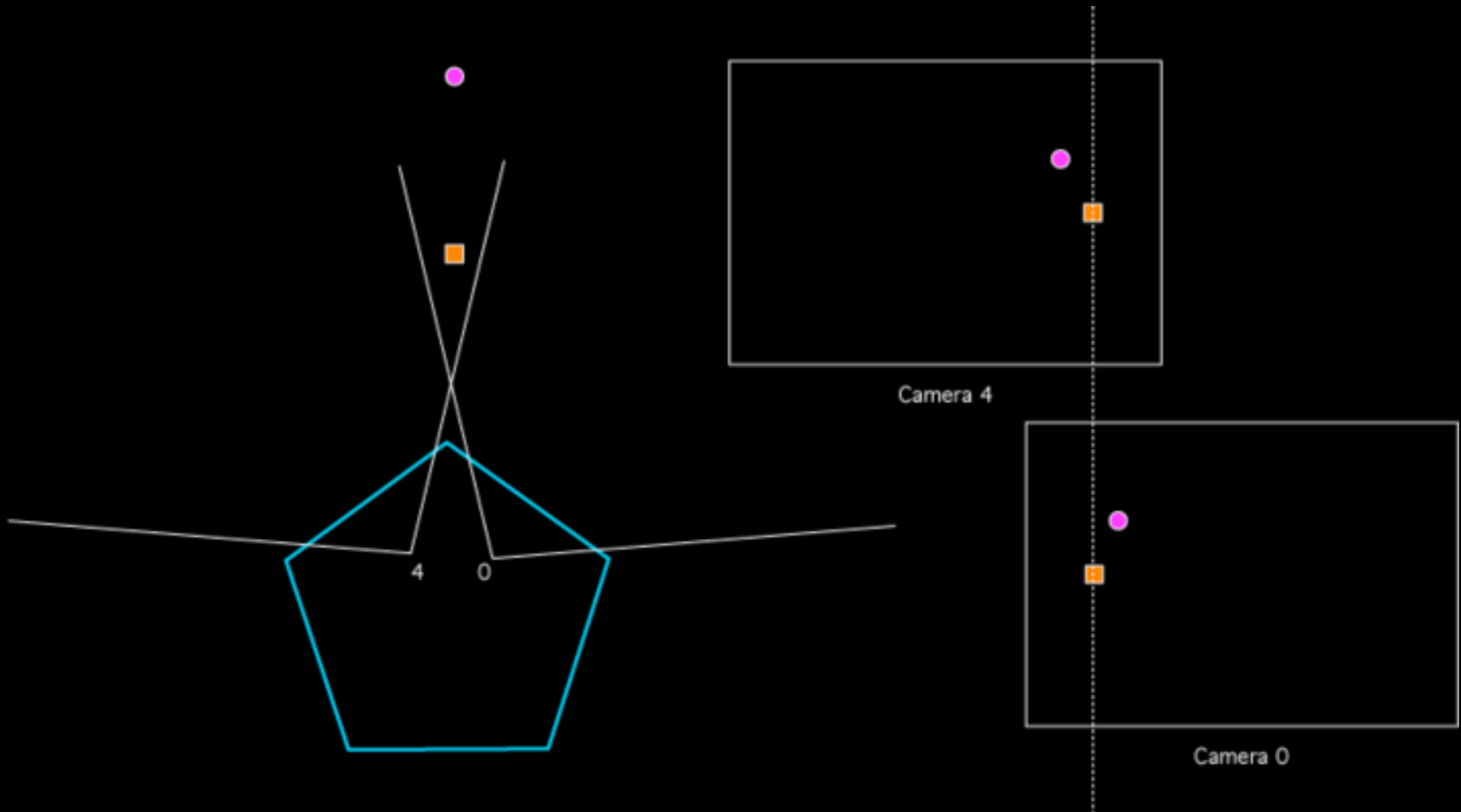


LadyBug camera

- Important settings during recording.
 - 8, 12 or 16 bit mode.
 - Compressed or uncompressed. (Uses jpg).
 - Exposure, shutter and colour processing.
 - Colour downsampling by 4 (recommended) during recording.
- Based upon machine vision cameras so one has low level control over camera hardware.
- For fastest frame rate video 12 bit half height is my preferred option, 16fps, jpg compressed. LadyBug-3 native resolution up to 16fps, LadyBug-2 resolution at 32fps. LadyBug-2 native resolution is 32fps.
- For time-lapse push it up to maximum of uncompressed 16 bit.
- Again, bandwidth to storage vs image quality/fps trade-off. Safe at up to 80MB/sec sustained to a dual RAIDed SSD drive.
- Important settings during export.
 - Blend/stitch range, see next slide.
 - Colour processing, high quality linear (Recommendation).
 - Mapping type of radial, no point cylindrical since there is no vertical angle control.
 - Set in and out points.
 - Select export projection, suggest "panoramic".
 - Select export resolution. 5400 for LB3 half height simulation mode, 8Kx4K for LB5 full resolution.
 - Export to 16bit tiff frames.

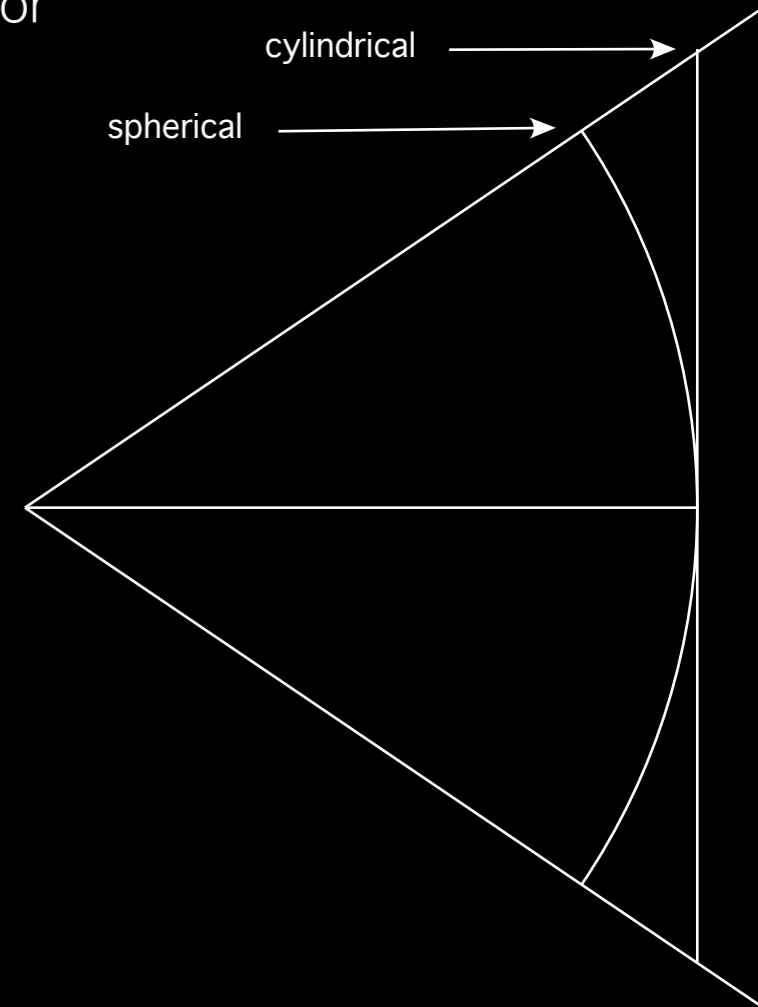
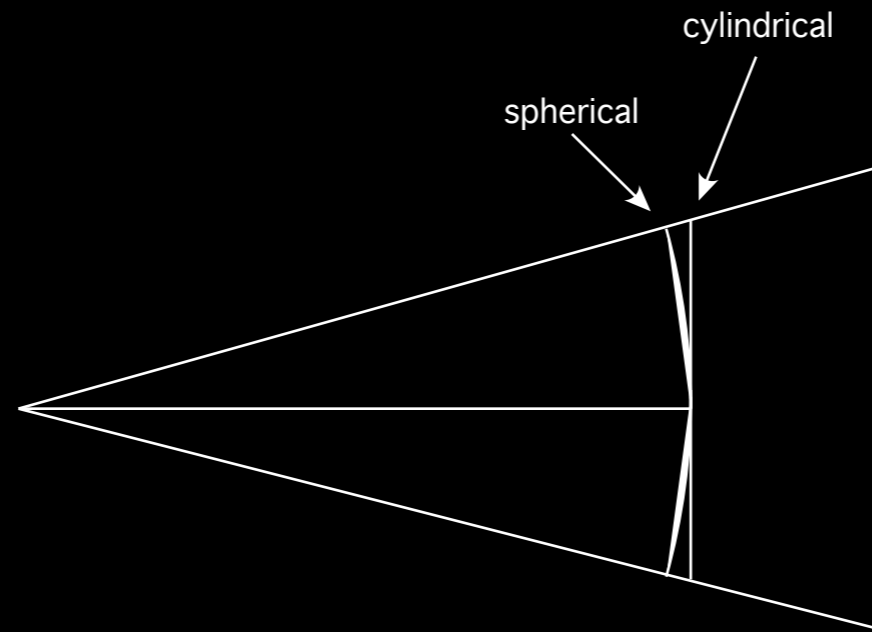
LadyBug camera

- Impossible to get a perfect blend/stitch at all depths for any multiple camera rig.
- Possible to get a perfect blend at any single depth.



LadyBug camera

- Can post process the footage to fisheye, not that exciting but allows change of view and orientation in post production. Or as 360 cylindrical movies for the cylindrical display.
- Note that this is not just a truncation of the spherical footage although for small vertical fields of view that may be close enough.



LadyBug camera

- Worked example.
- Export from PGR files and process in AfterEffects.
- Need to work on a steady rig not trivial.



LadyBug camera

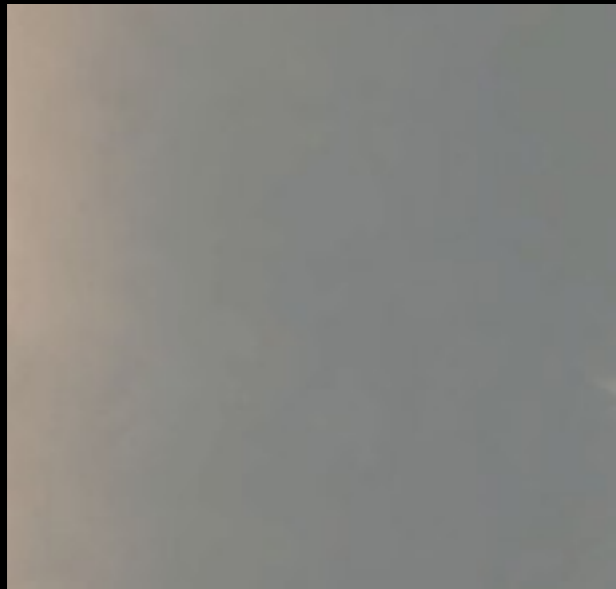
- After effects
 - Create composition at same frame rate as capture.
 - Set frame import to 1 frame per composition frame.
 - Dimensions the same as the PGR export (do any scaling in export).
 - Retain 16bit during processing pipeline.
- Common operations
 - Colour correction - Shadows and hi lights - Vibrance - Possibly sharpen
- Can try time-flow methods to upscale frame rate.
- Be careful with filters that require information from surrounding pixels, AE does not know the left and right edges are adjacent.
- Re-orient “front” by duplicating footage and aligning to left or right.
Also solves edge filer problems.



Unity3D

- Summary from seminar
 - Two methods (at least), vertex shader and cube rendering.
 - Disadvantage of the first is it also needs tessellated geometry.
 - Advantage of the vertex shader is it is a single pass.
 - Advantage of the cube render is generality.
 - Will discuss the cube render here.
- Pipeline: 4 render to texture passes, one render pass of fisheye image, final render to screen.
 - With a loss of generality can go direct from 4 cube render to warped image.
 - Performance hit is about a factor 2.5.
- Limitations
 - Billboard textures that depend on camera normal, can cause disjoint textures between cameras.
 - Non-3D effects, for example lens flare applied in image space.
 - Performance implications.

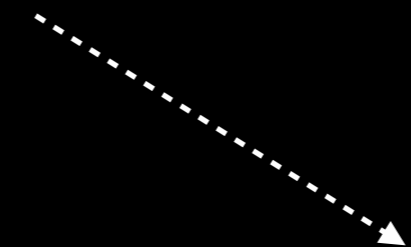
Unity3D



Fisheye view



4 cube views

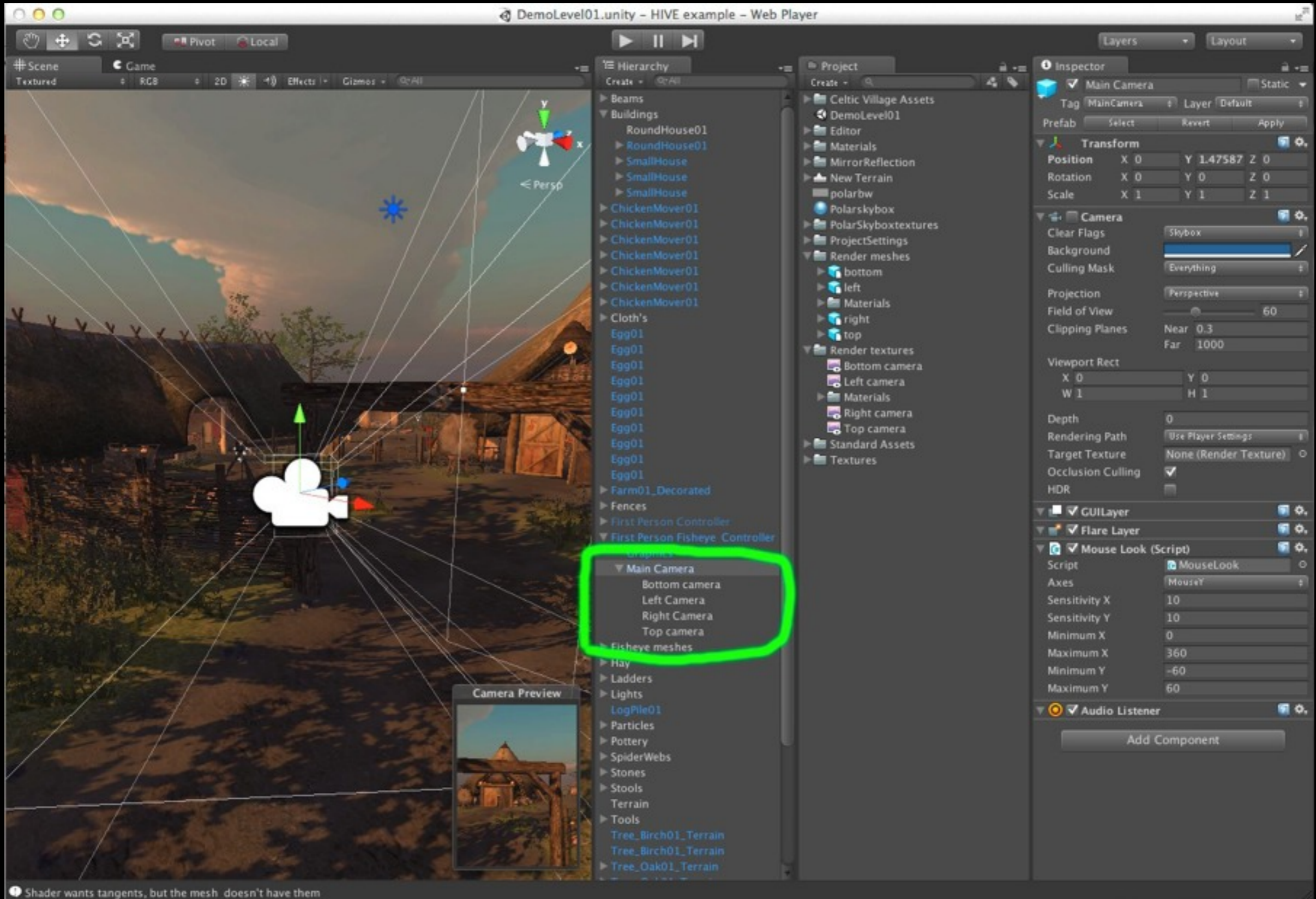


Warped fisheye view



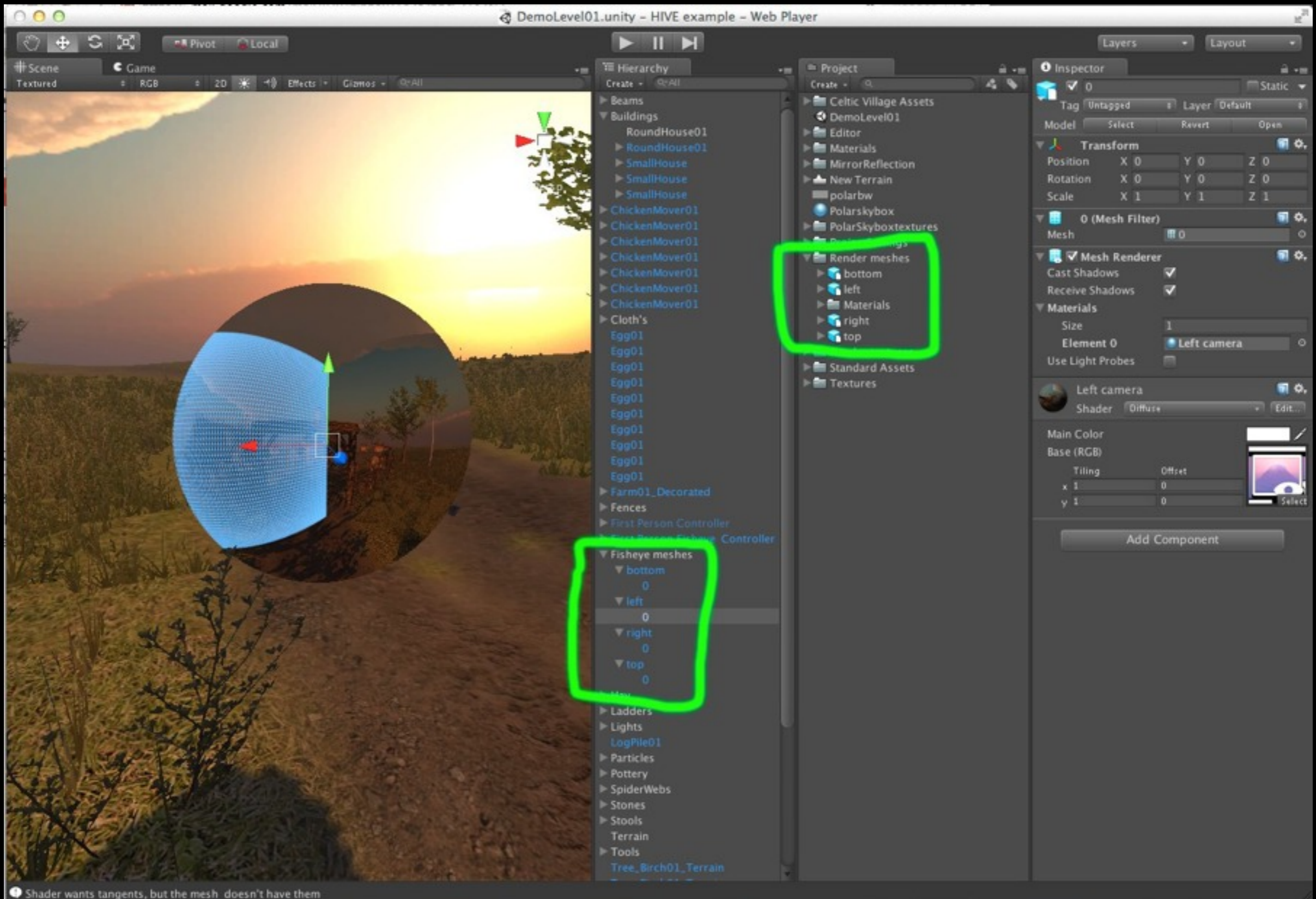
Unity3D

- Create multiple camera rig



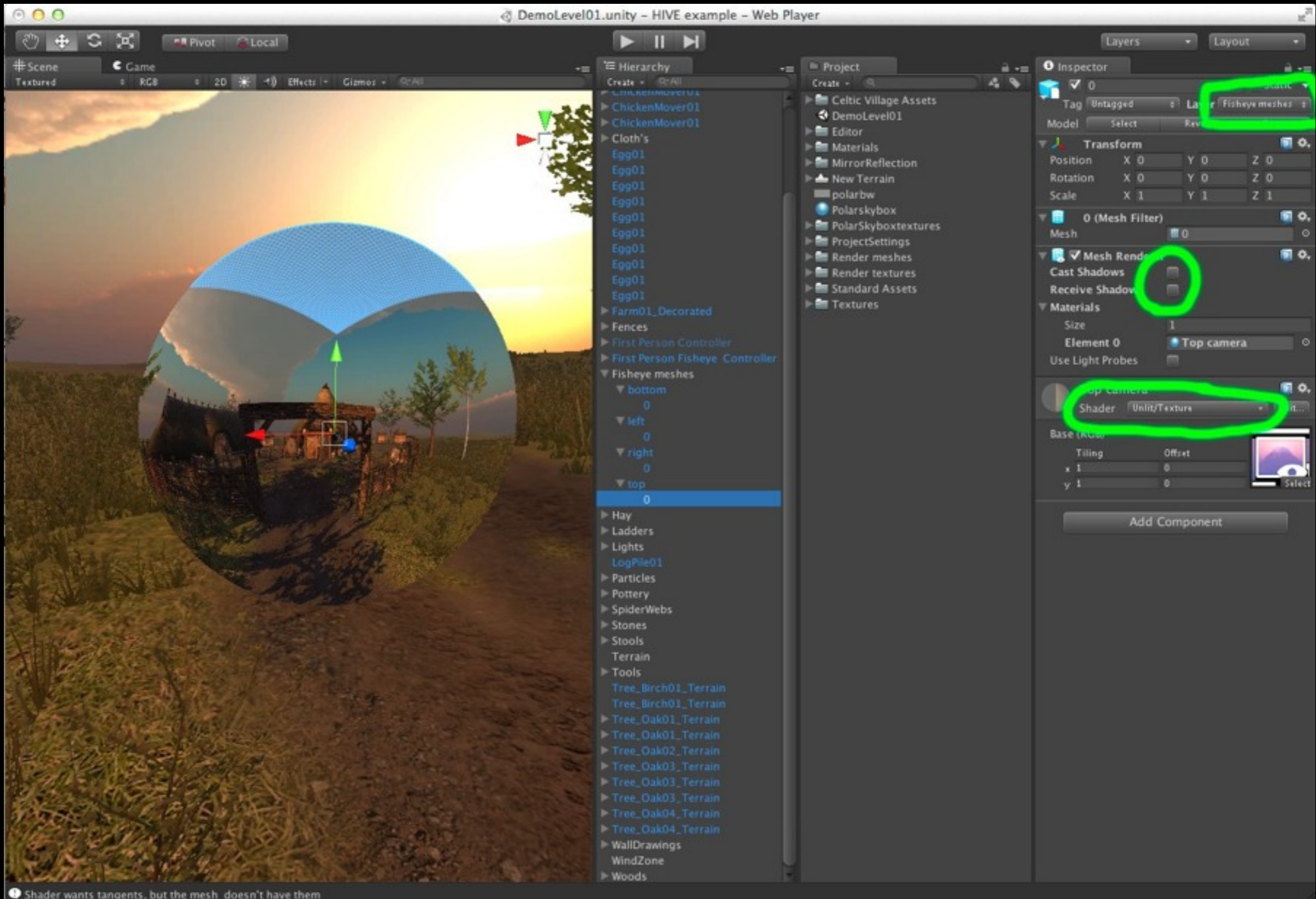
Unity3D

- Import 4 meshes for fisheye, assign render-to-texture to each.



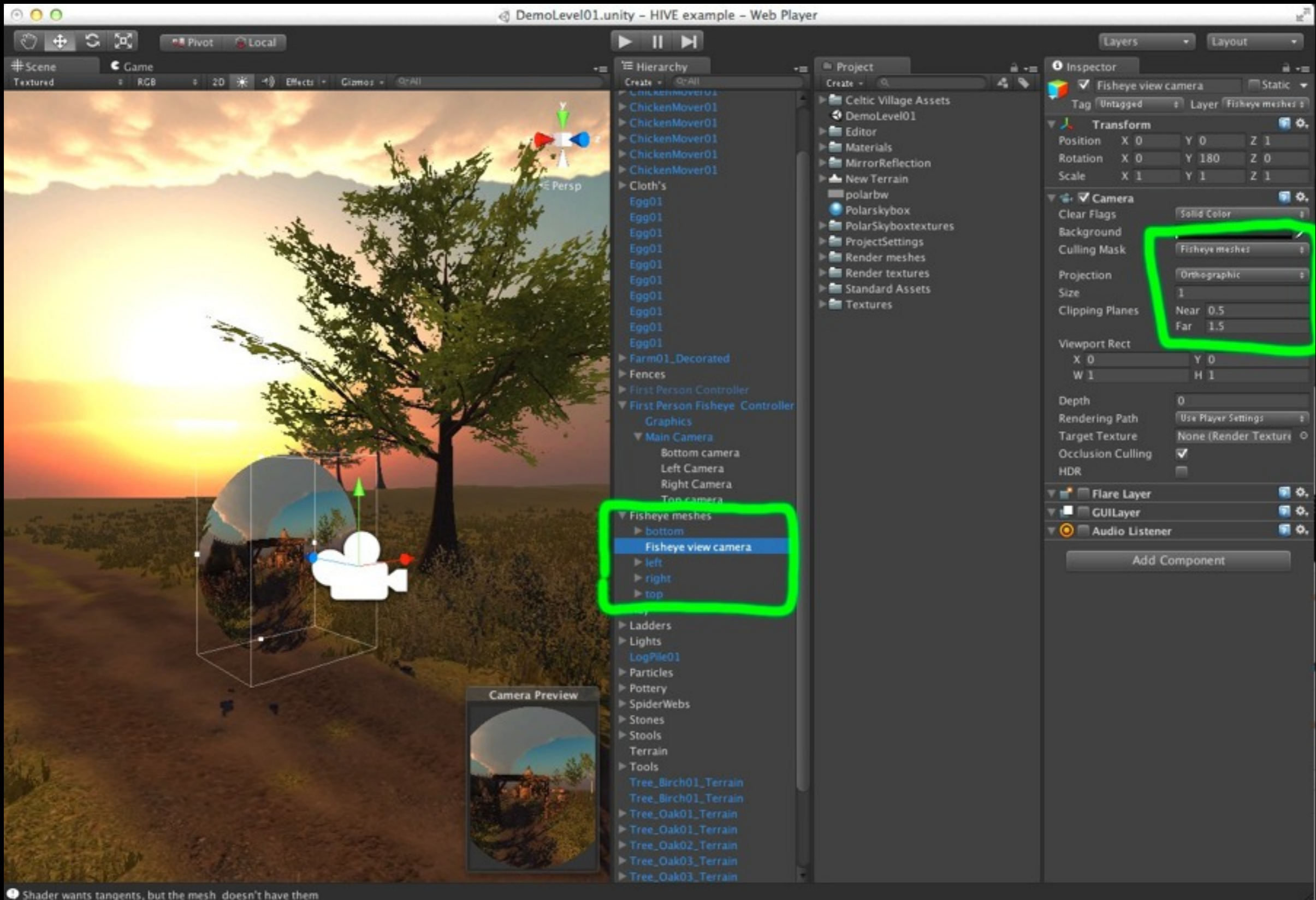
Unity3D

- Create new layer, exclude scene lighting, set unlit textures, remove shadows.



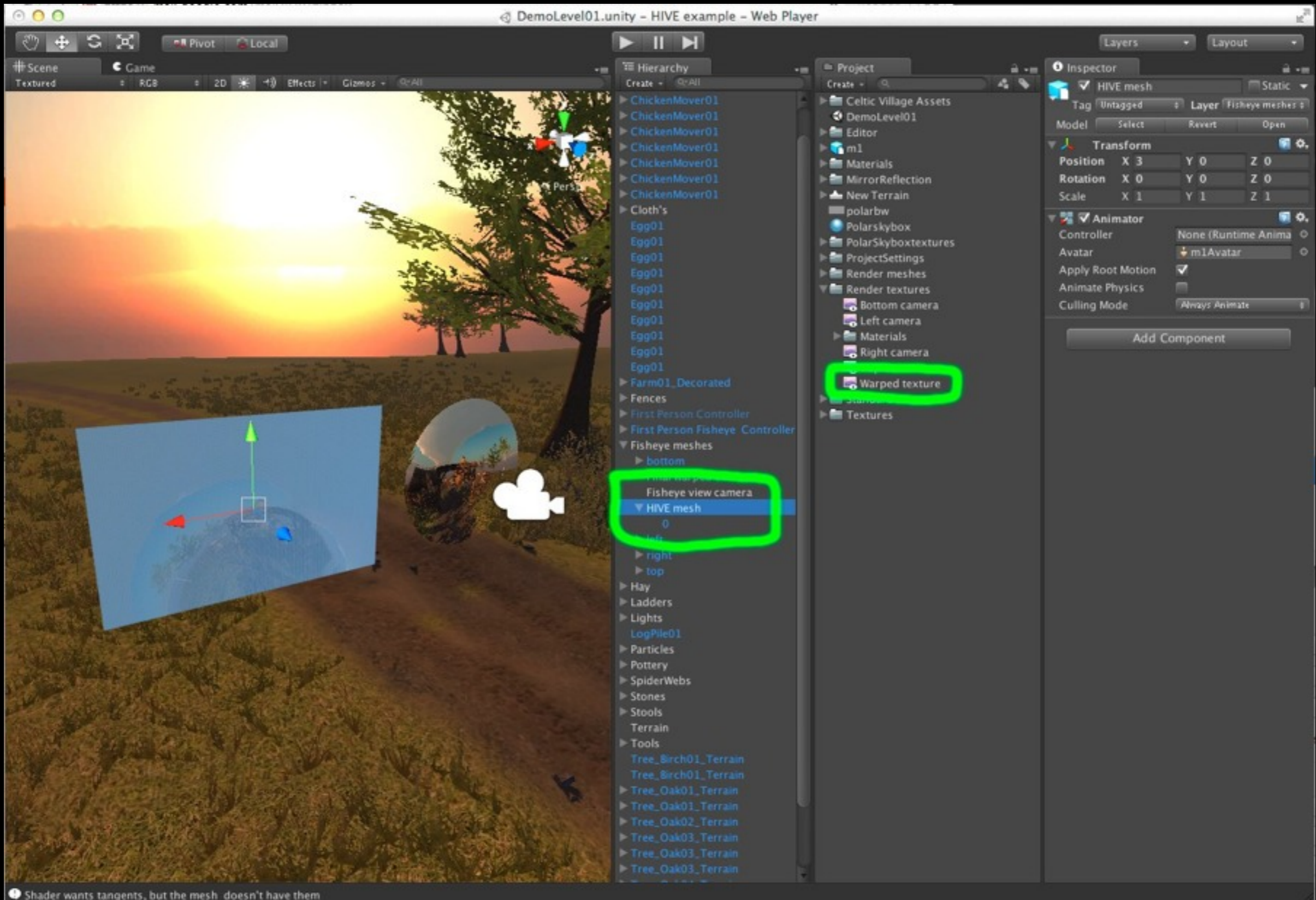
Unity3D

- Remove fisheye layer from 4 cameras, assign ortho camera to fisheye mesh view.



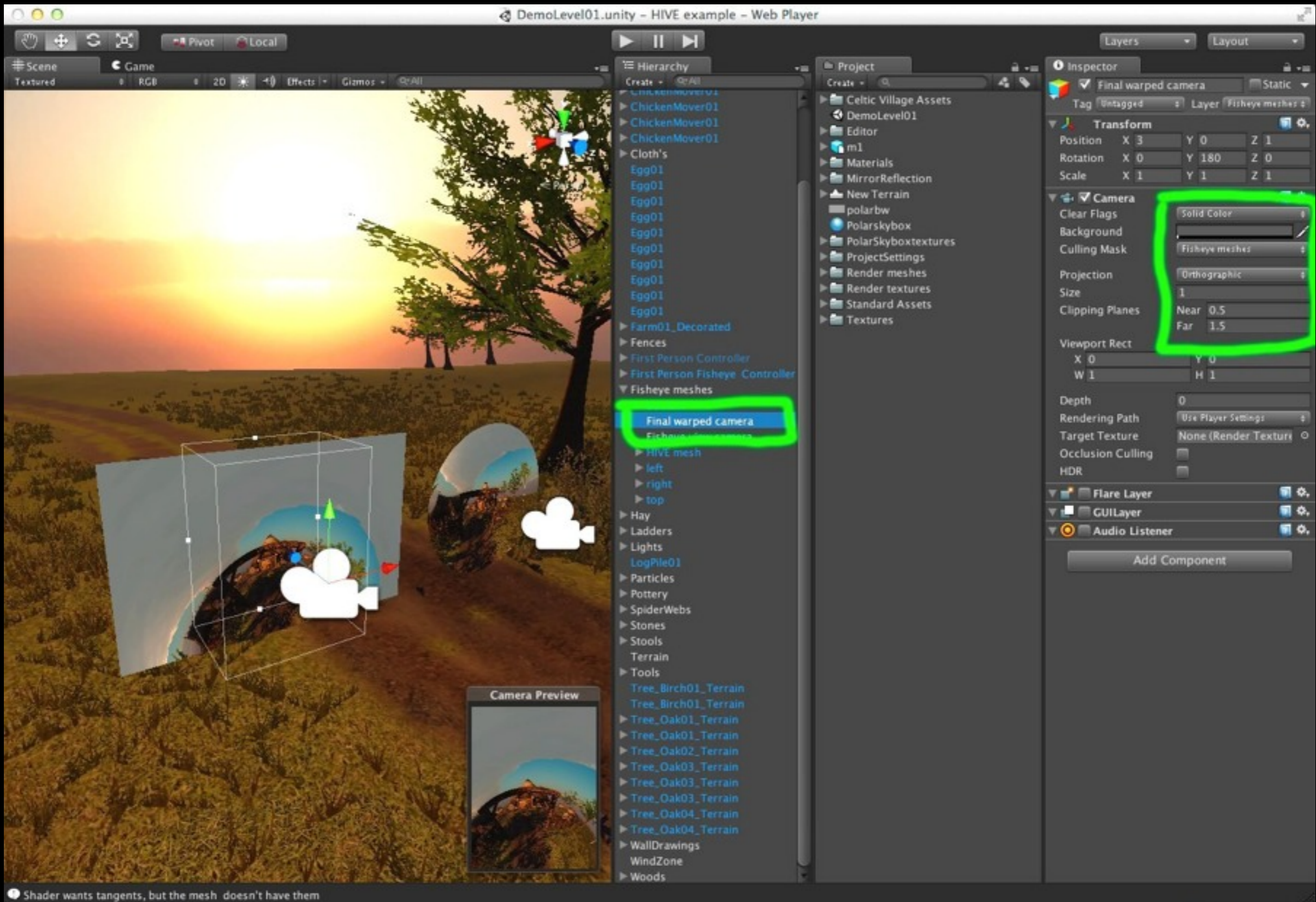
Unity3D

- Fisheye camera render to texture, add HIVE specific mesh.



Unity3D

- Add final camera to view warp mesh.



Unity3D

- Show key features live.



End