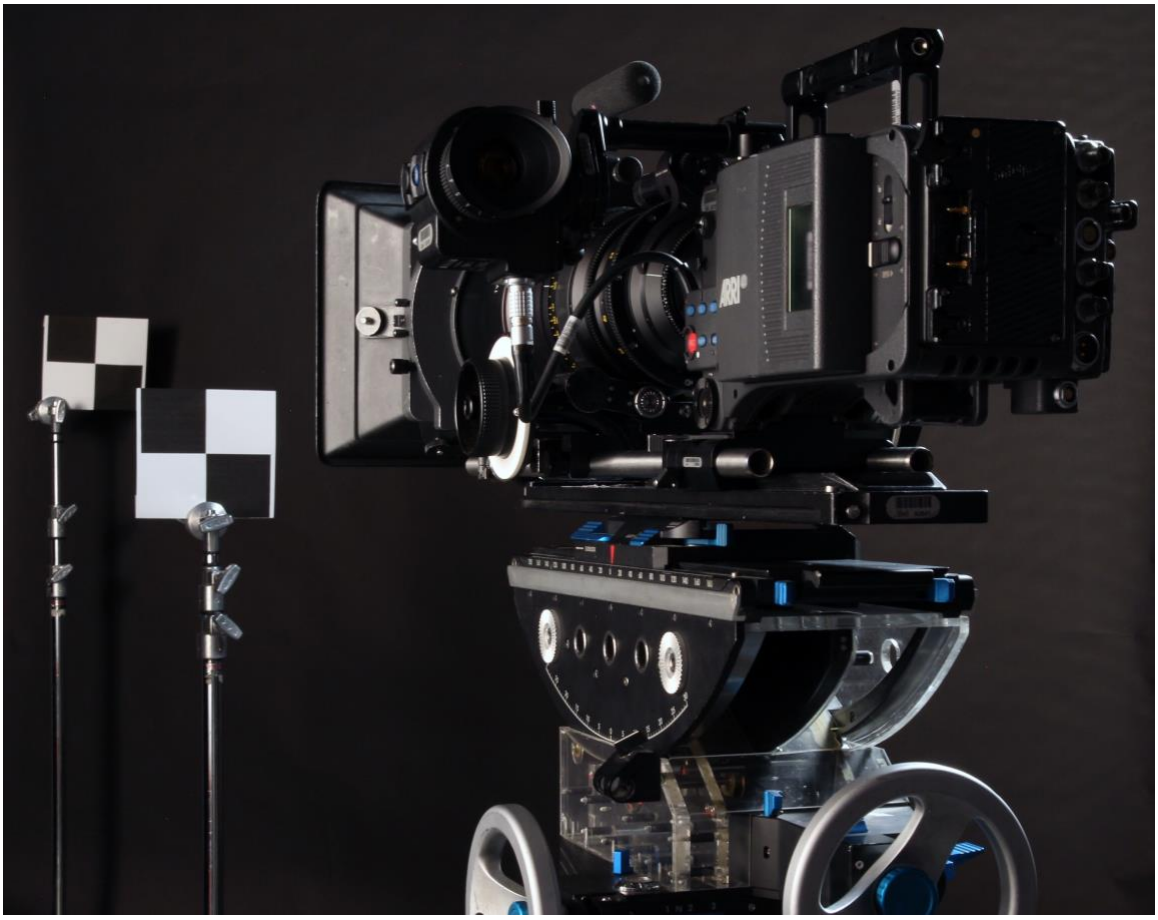
Empirically Finding the Entrance Pupil of a Lens

1. From Wikipedia; Entrance Pupil of a Lens - The geometric location of the entrance pupil is the vertex of the camera's angle of view[1] and consequently its **center of perspective**, **perspective point**, **view point**, **projection centre**[2] or **no-parallax point**.[3] This point is important in panoramic photography, because the camera must be rotated around it in order to avoid parallax errors in the final, stitched panorama.[4][5] Panoramic photographers often incorrectly refer to the entrance pupil as a nodal point, which is a different concept. Depending on the lens design, the entrance pupil location on the optical axis may be behind, within or in front of the lens system; and even at infinite distance from the lens in the case of telecentric systems.

I will sometimes refer to the entrance pupil as the no parallax point to emphasize its significance to cinematographers and vfx supervisors. As noted in the definition above, cinematographers need to grasp the value of the entrance pupil in cases such as shooting adjacent plates to be stitched together in post.

We can empirically find the entrance pupil of a lens by shooting two targets on C-stands, lined up in a row so that one partially blocks the other. We will need two printed cards with black and white squares, two c-stands, a gearhead on a tripod or dolly, a camera and a lens. On a fluid head like an O'Connor 2575 the center of the tilt axis rotation is at the middle of the head, making it impossible to use in this case. An "L" type head like a Cartoni Lambda, Weaver-Steadman, or Ronford F7 head the lens can be centered at the rotation points of the pan and tilt axes. Placing the lens entrance pupil at the centers of rotation on an "L" head usually ends up with a very back heavy camera arrangement. An Arrihead or a Panahead or other geared head will allow you to place the lens at the center of the pan and tilt rotation axes and still manage balancing the camera.



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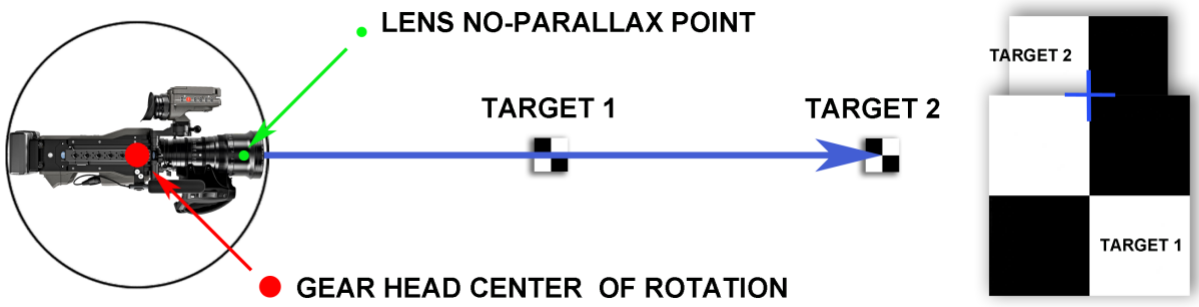
- Caption: Figure 7-89 Stage Setup for Finding Entrance Pupil Position

Mount the two cards at the top of the c-stands at lens height, straight and level at set one stand about 6 feet from the camera and the other at about 12 feet from the camera.



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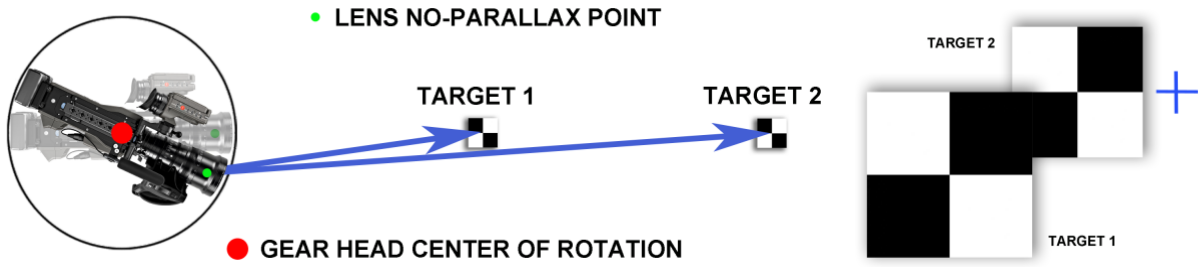
Caption: Figure 7-90 Setting up targets in order to find the lens' entrance pupil

Line the two targets up on the crosshairs of the viewfinder so that one set of squares is visible above the other, aligned at the center.



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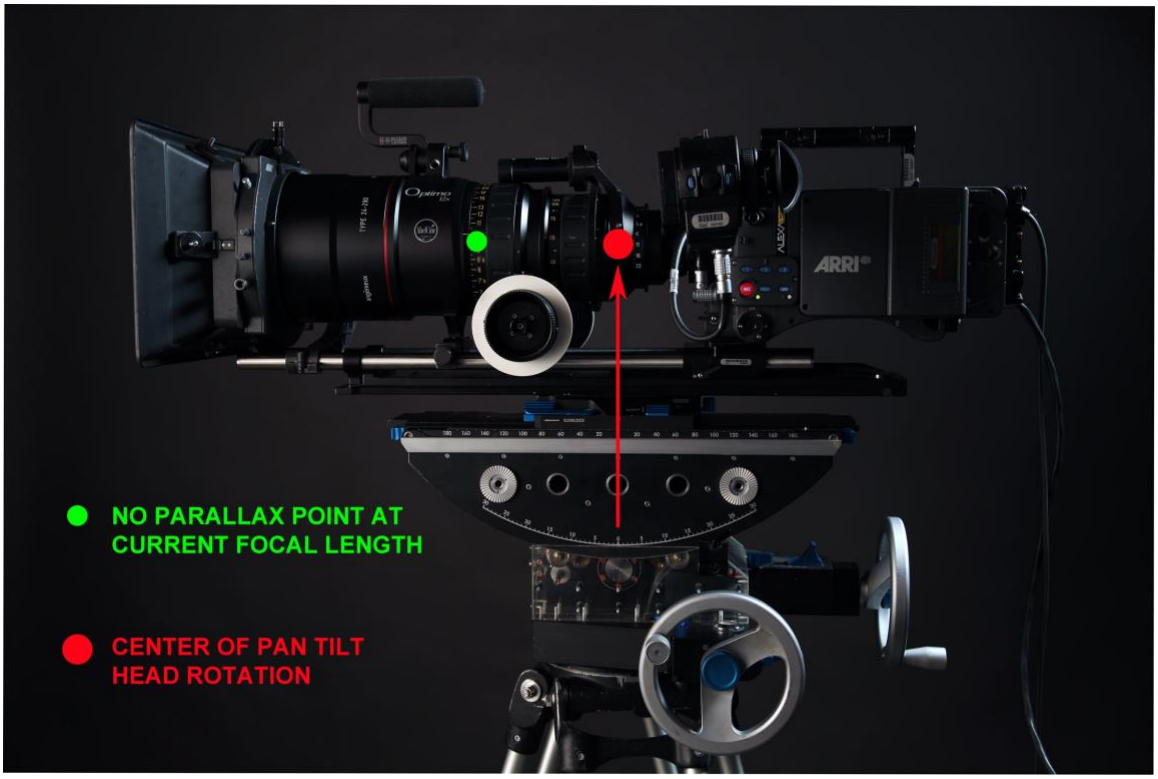
Caption: Figure 7-91 The Relationship of the Charts Changes as the Camera is Panned

In this case, when we pan to the right, the two targets will probably move out of alignment slightly (unless you have accidentally placed the lens entrance pupil precisely on the gearhead center of rotation!), and when we pan left, they will move out of alignment by the same amount in the opposite direction. This parallax shift indicates that the lens' entrance pupil is forward of the center of rotation of the pan tilt head.



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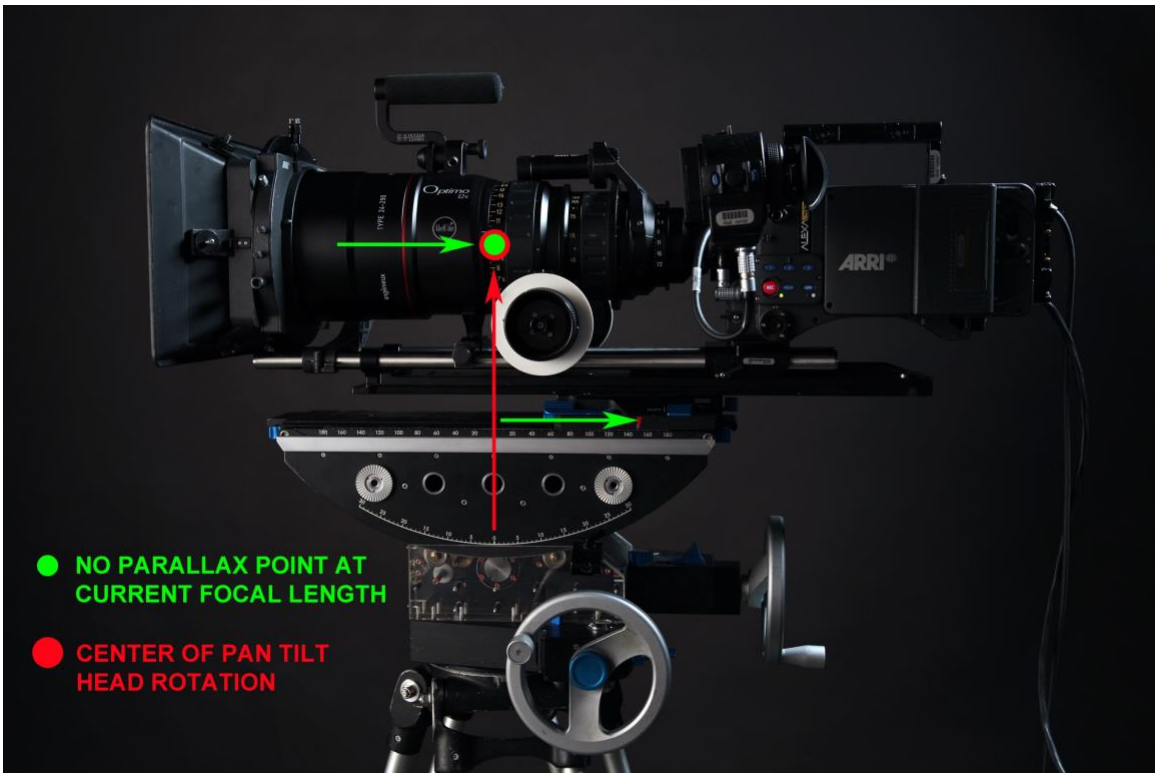
Caption: Figure 7-92 Relationship of Lens Entrance Pupil and P/T Head Center of Rotation



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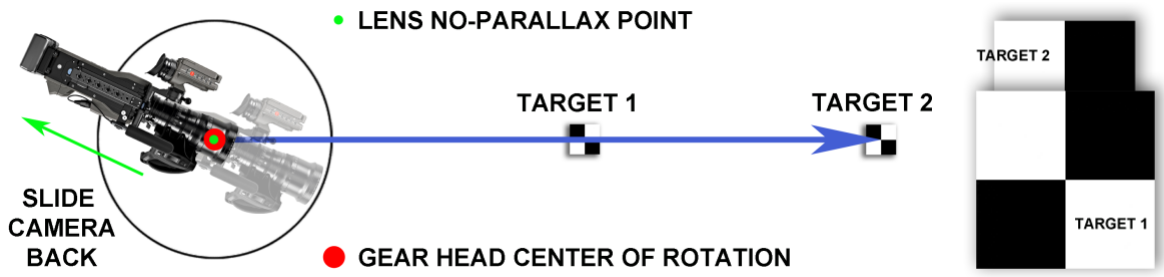
Caption: Figure 7-93 Aligning the Entrance Pupil to the P/T Head Center of Rotation

With the camera panned until the two charts are at the edge of frame to one side or the other, loosen the detent on the gear head's balance plate and slide the camera back (or forward as needed) until the two charts are aligned again. When the lens is over the rotation point of the head, the camera may become back heavy, so exercise caution when releasing the tilt lock detent.



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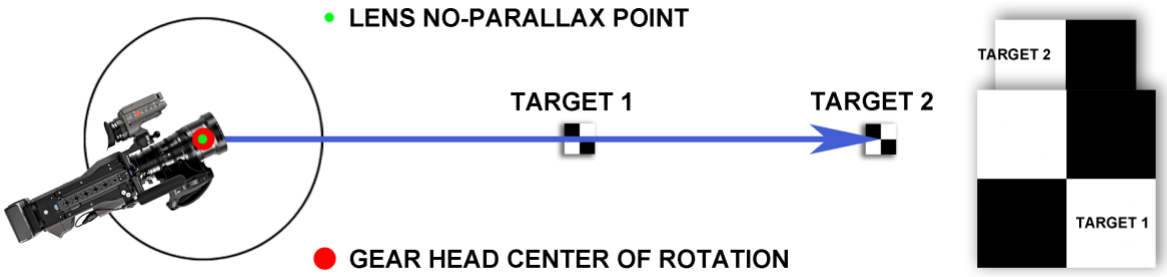
Caption: Figure 7-94 Aligning the "no-parallax point" at the Center of Rotation



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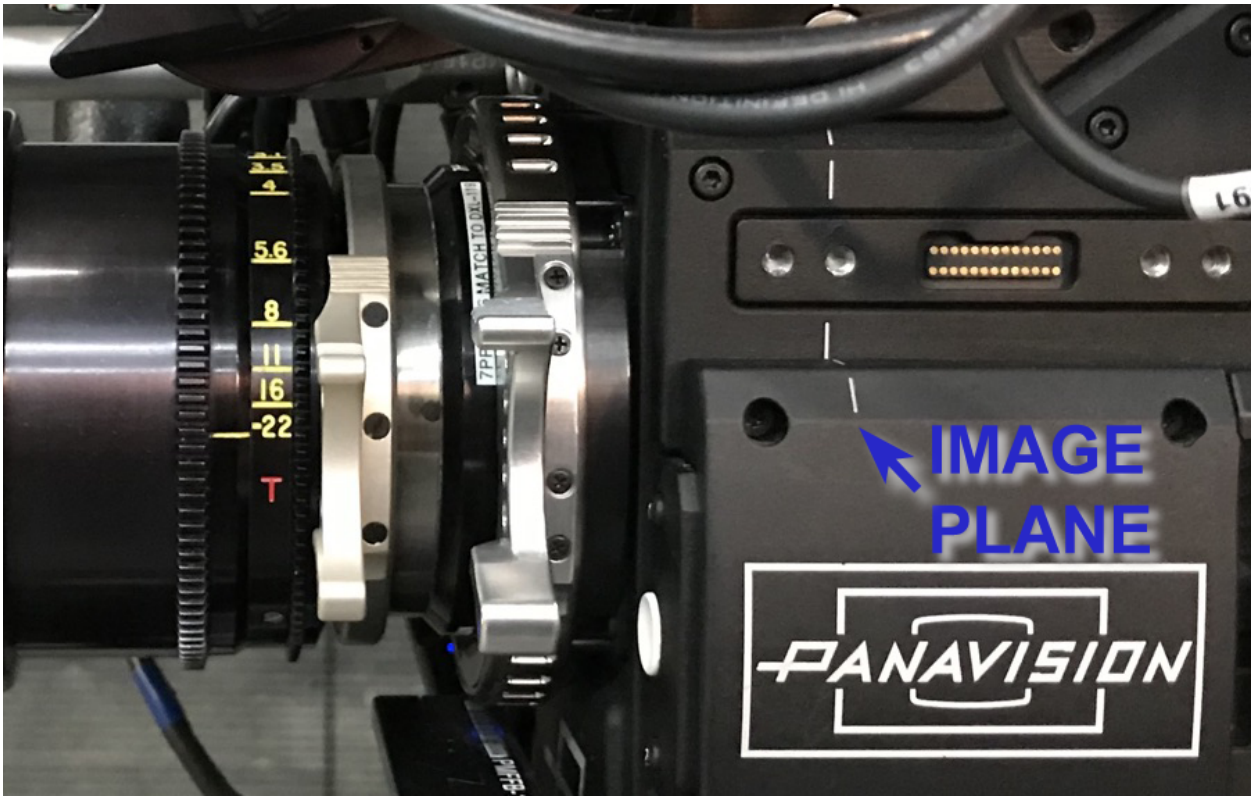
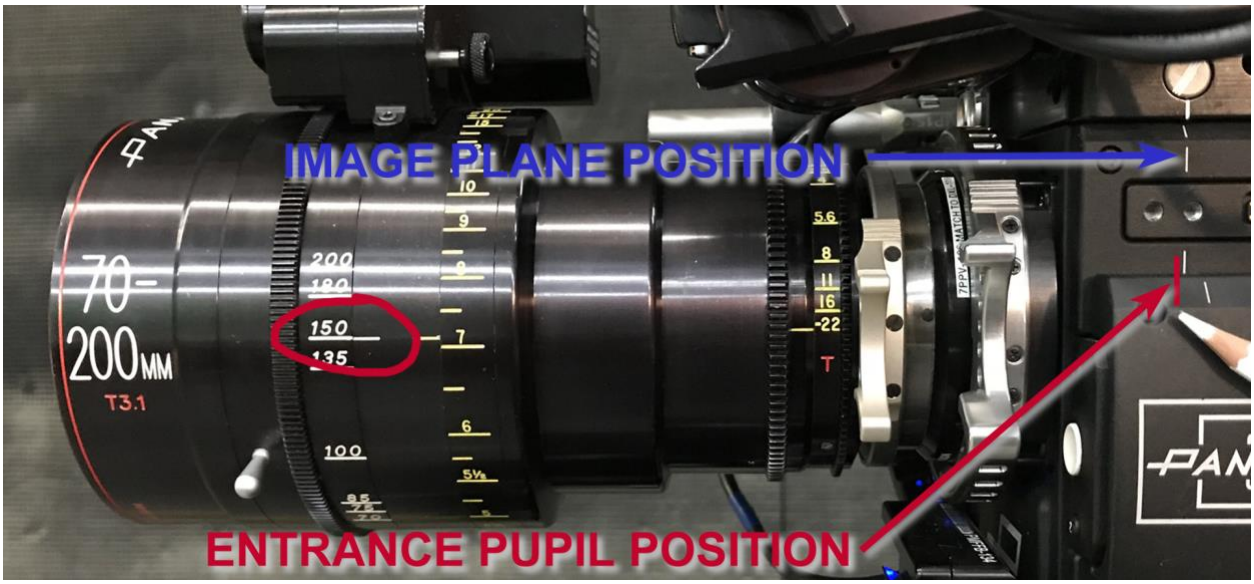
Caption: Figure 7-95 Once Aligned, Panning or Tilting the Camera Does Not Affect Parallax

Pan back and forth to move the charts from one side of frame to the other and observe that their alignment doesn't change. We no longer observe any parallax shift between objects at different distances from the camera as we pan and tilt. When the relationship between the two charts remains constant as we pan, we have successfully placed the entrance pupil directly over the center of rotation of the gear head. If you set the lens at the entrance pupil before shooting panoramic plates or tiles the images can be stitched more easily, as fixed objects in the scene do not move from one tile to the next, regardless of distance from the camera.

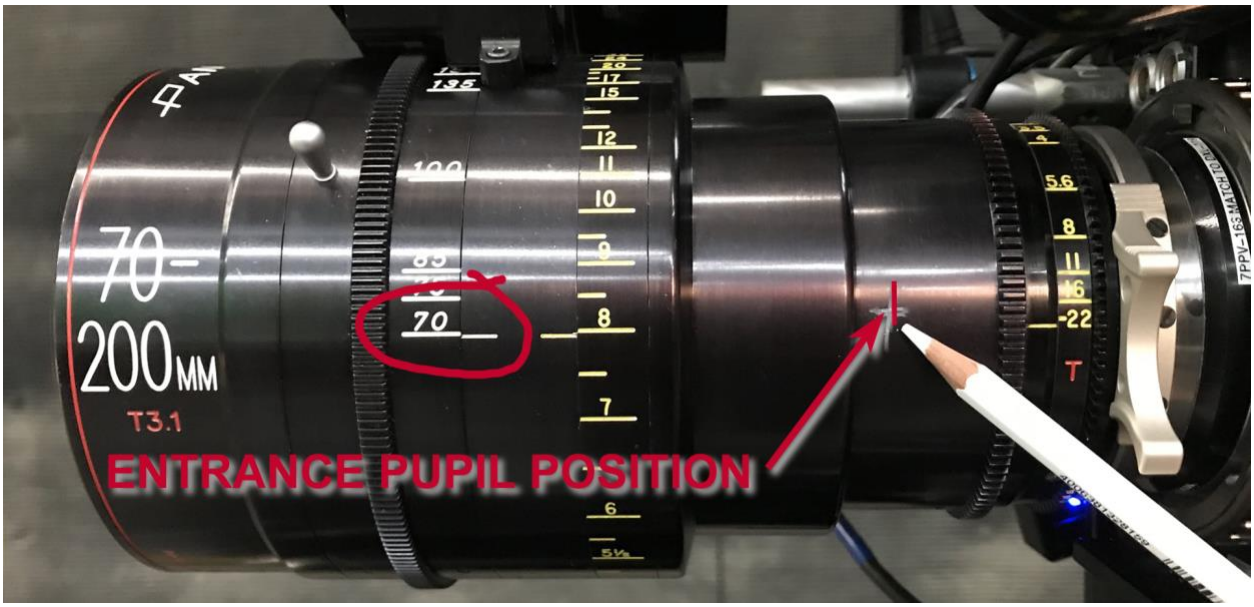
If we follow this procedure, we eventually discover that the entrance pupil of a lens can be located outside the lens, and that it can be located variably in zoom lenses as a function of focal length. In the examples below, a 70 to 200mm Panavision zoom lens, the entrance pupil position changes radically as the focal length changes.



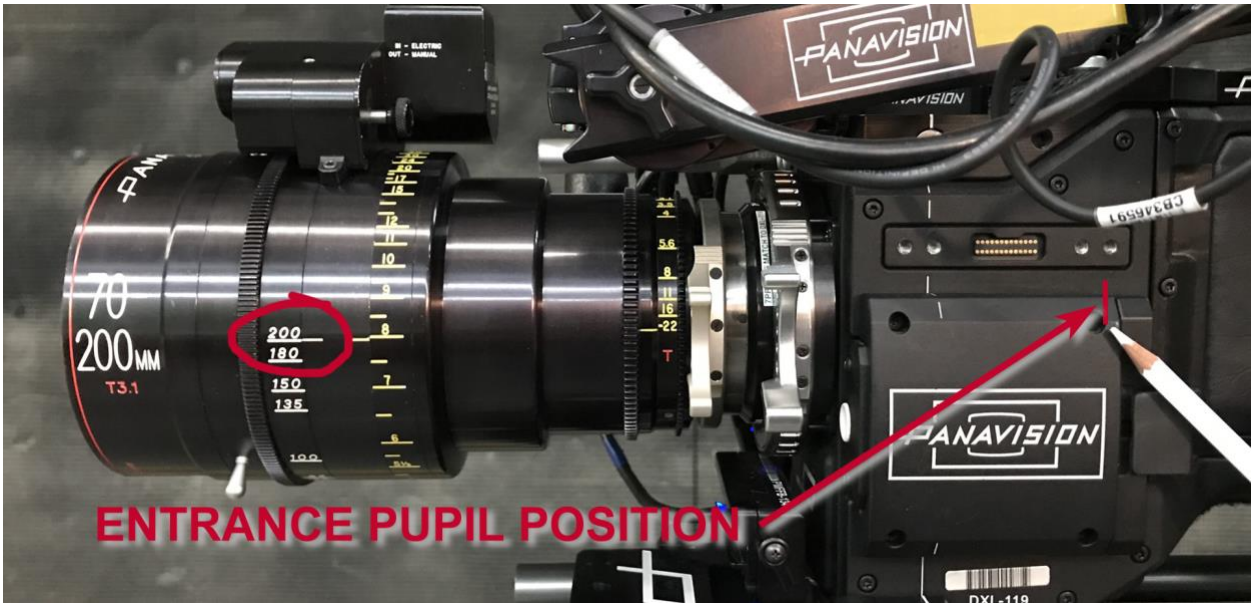
The image plane is located at a fixed distance from the lens mount flange surface.



On a Panavision 70 to 200mm zoom lens set at 150mm on the zoom, the entrance pupil position is located at approximately the same position as the image plane.



When the 70 to 200mm lens is set to its minimum focal length of 70mm, the entrance pupil is located inside the lens, somewhat forward from the iris.



When the same lens is set to the maximum focal length of 200mm, the entrance pupil location is well past the image plane, almost to the back of the camera body.

For the purpose of defining standards for lens metadata for SMPTE, it seems to me that this raises issues when speaking about the measured focal distance as a function of entrance pupil position!