Perception: How to compute intrinsics from vanishing points

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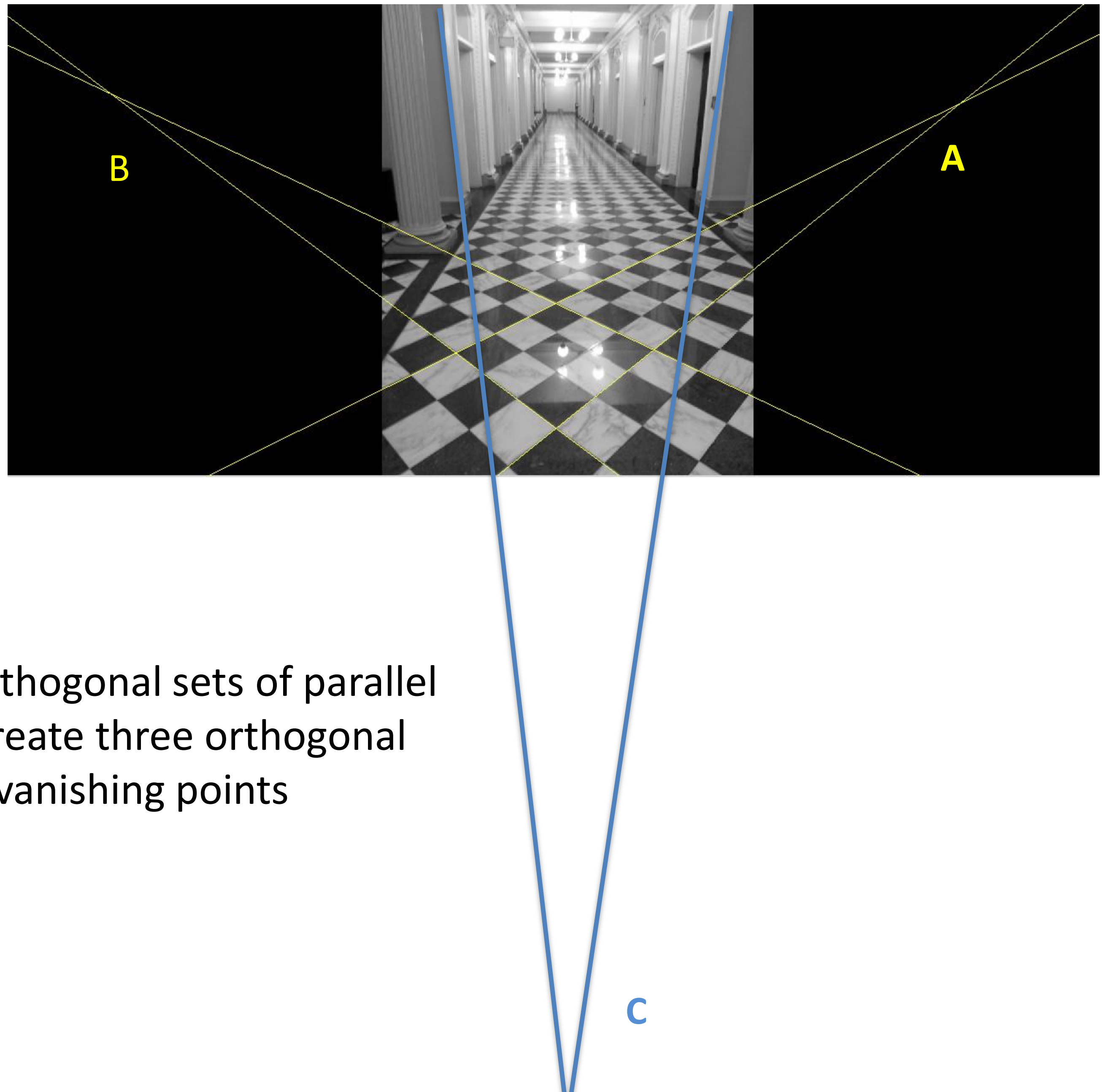
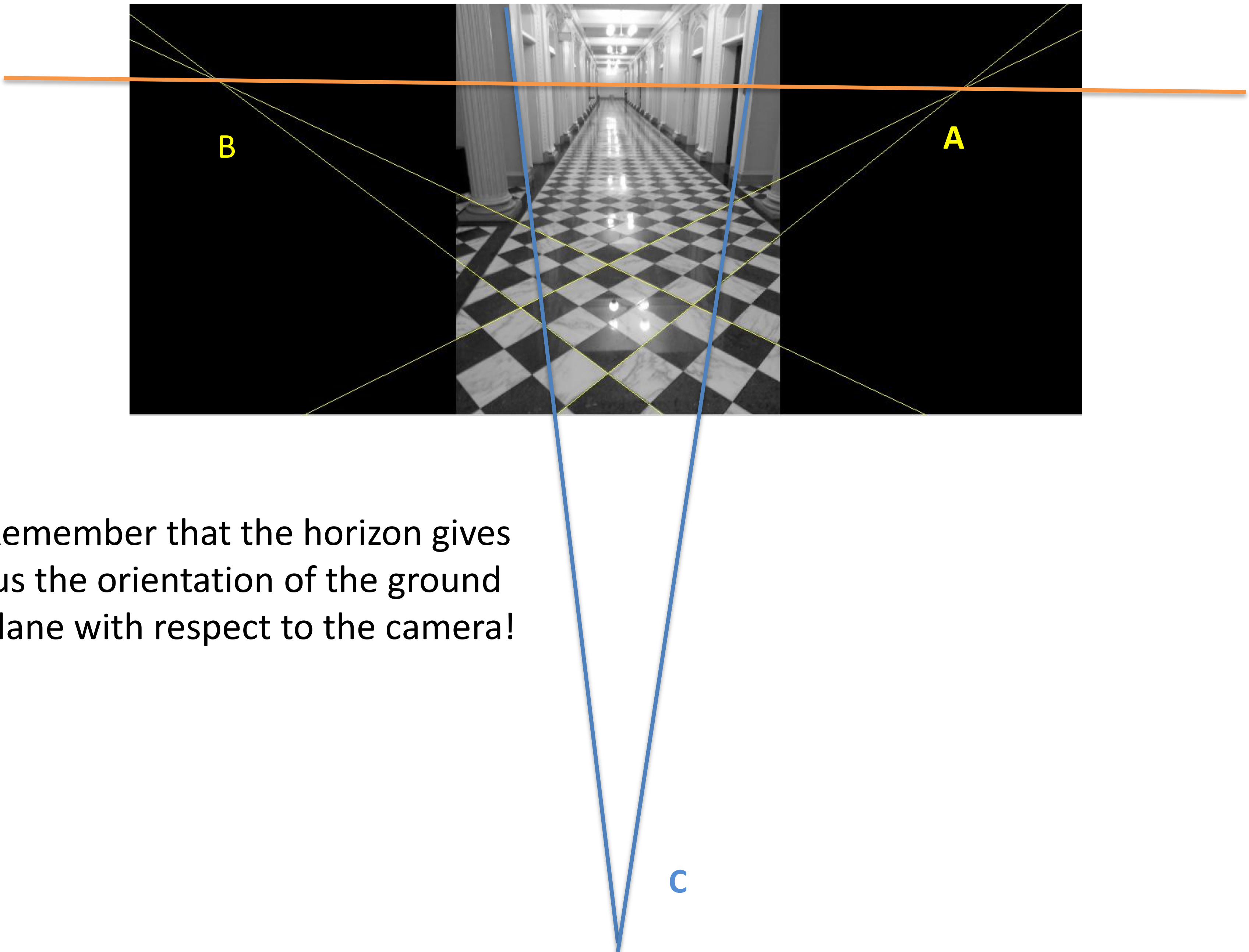
Manhattan world: A scene with three orthogonal sets of parallel lines



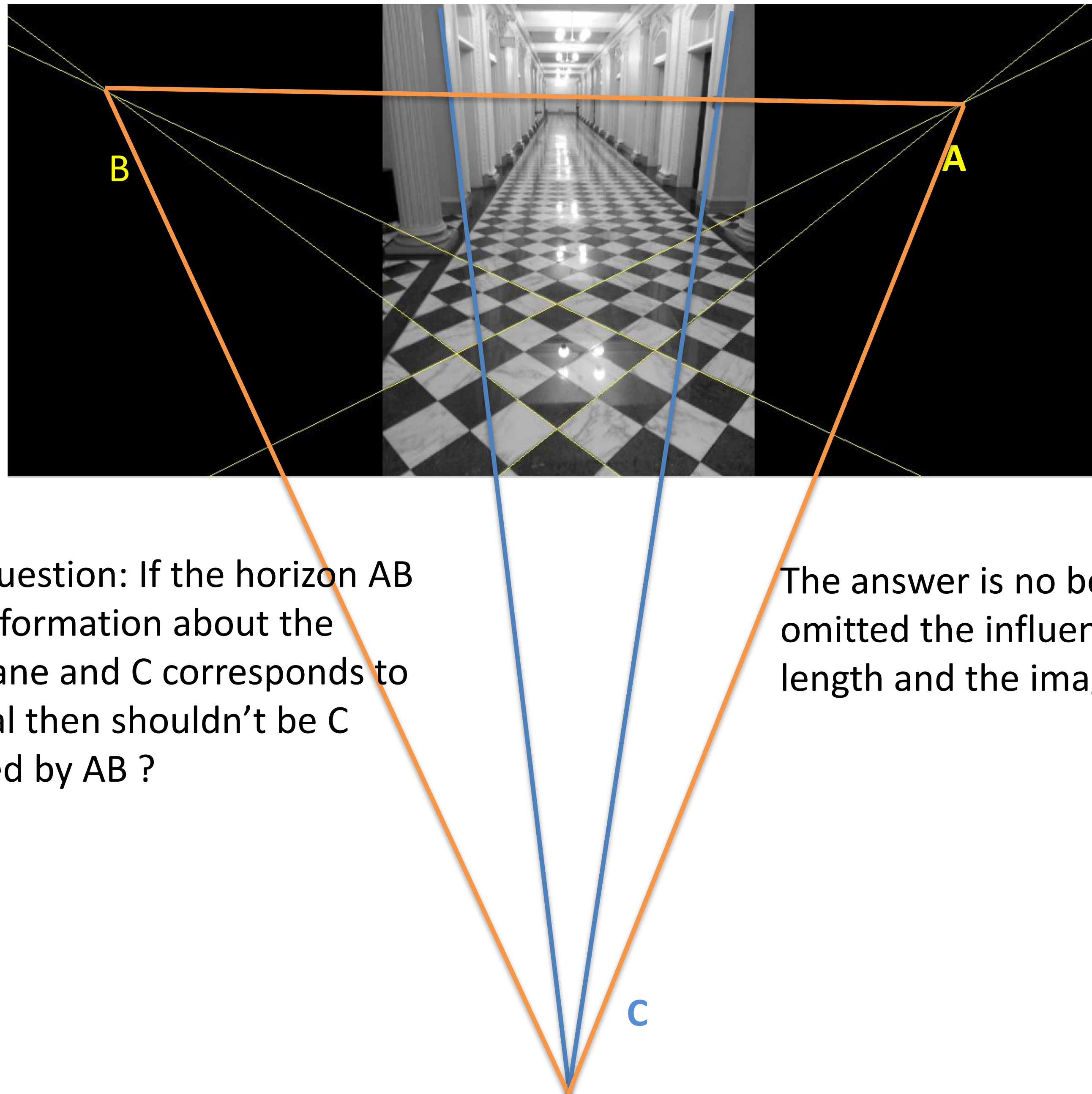
Three orthogonal sets of parallel lines create three orthogonal vanishing points

Line connecting AB is the horizon!



Remember that the horizon gives us the orientation of the ground plane with respect to the camera!

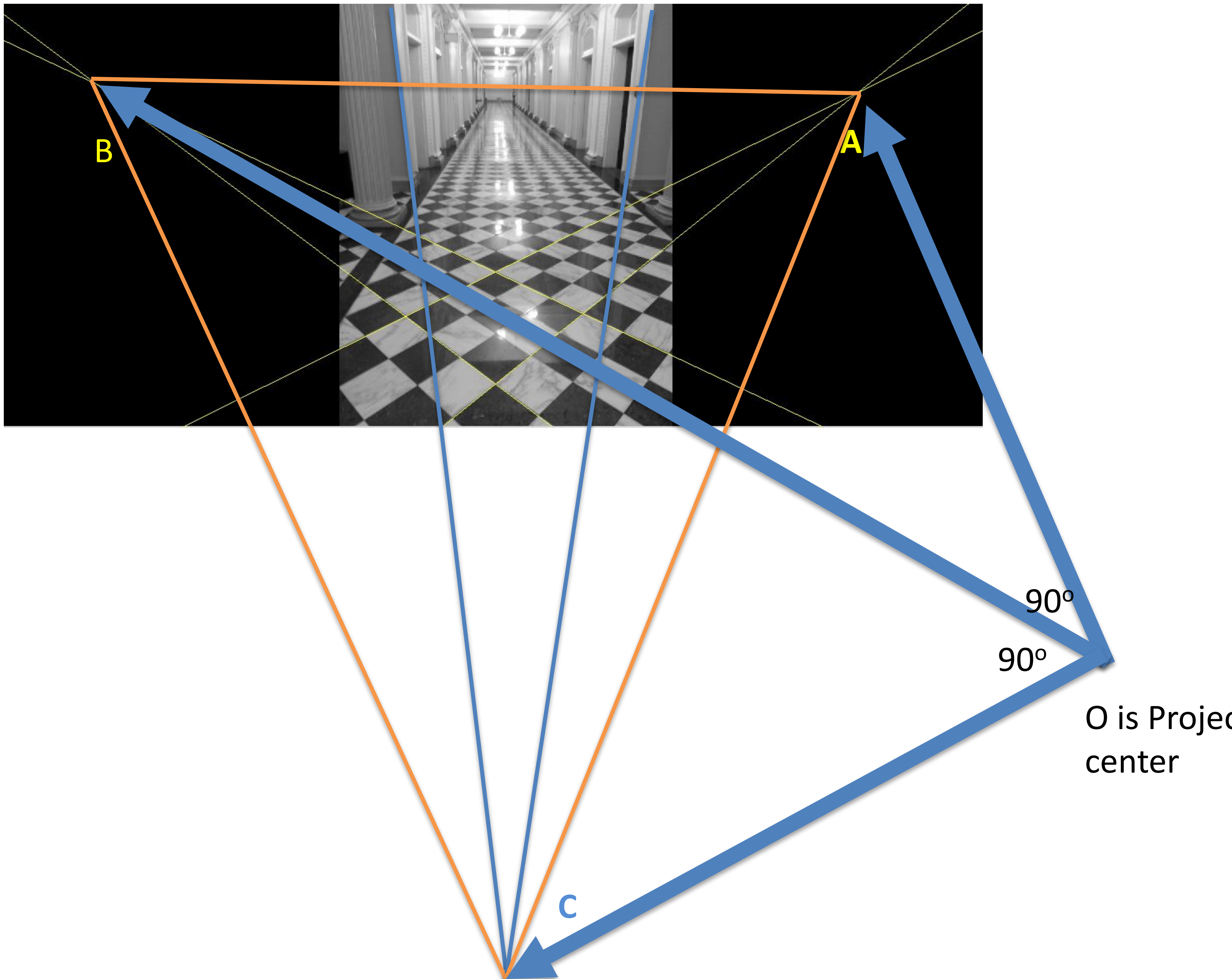
C is the vertical vanishing point!



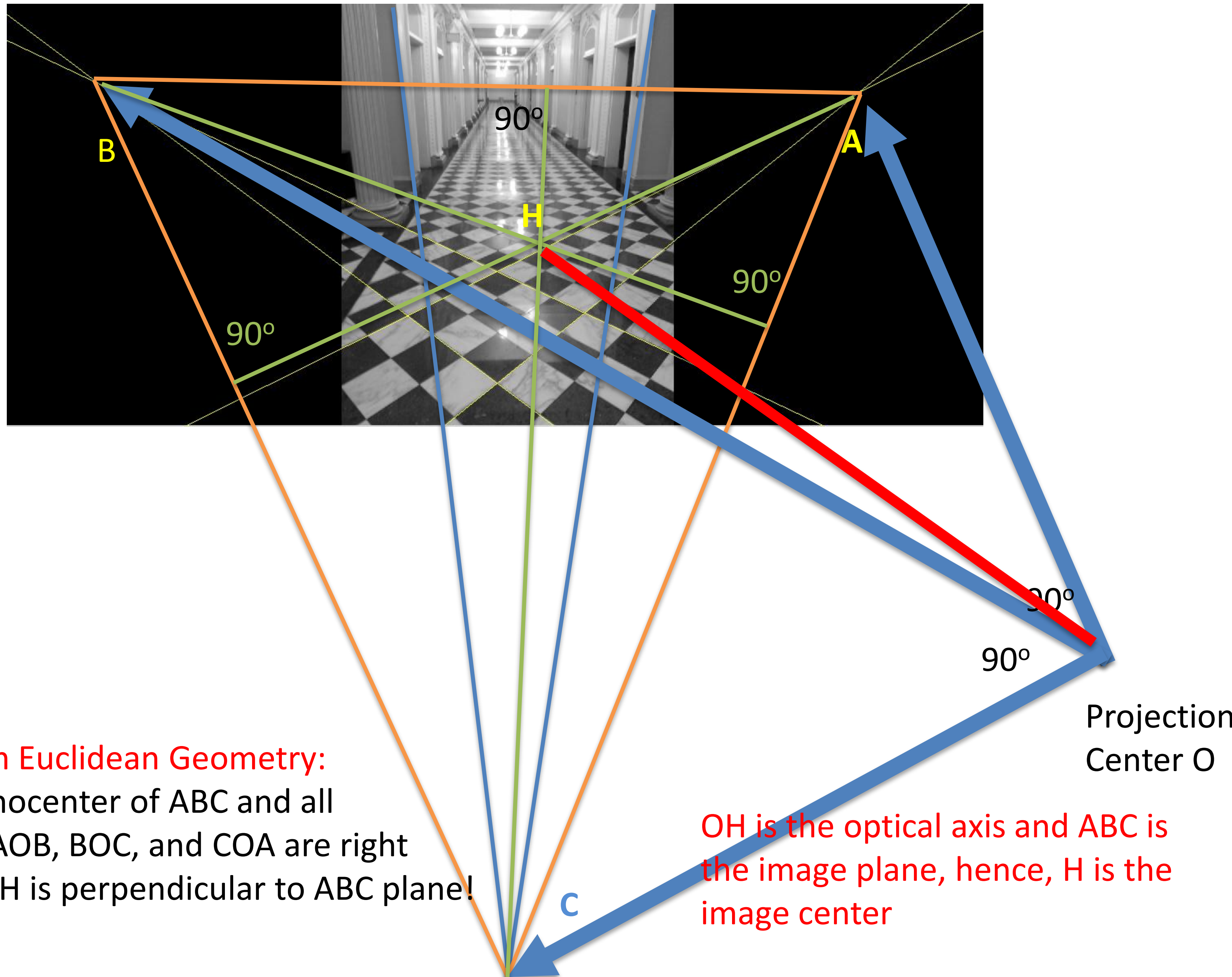
Obvious question: If the horizon AB gives us information about the ground plane and C corresponds to the vertical then shouldn't be C determined by AB ?

The answer is no because we omitted the influence of the focal length and the image center.

Let’s look at ABC as a tetrahedron OABC incl the projection center



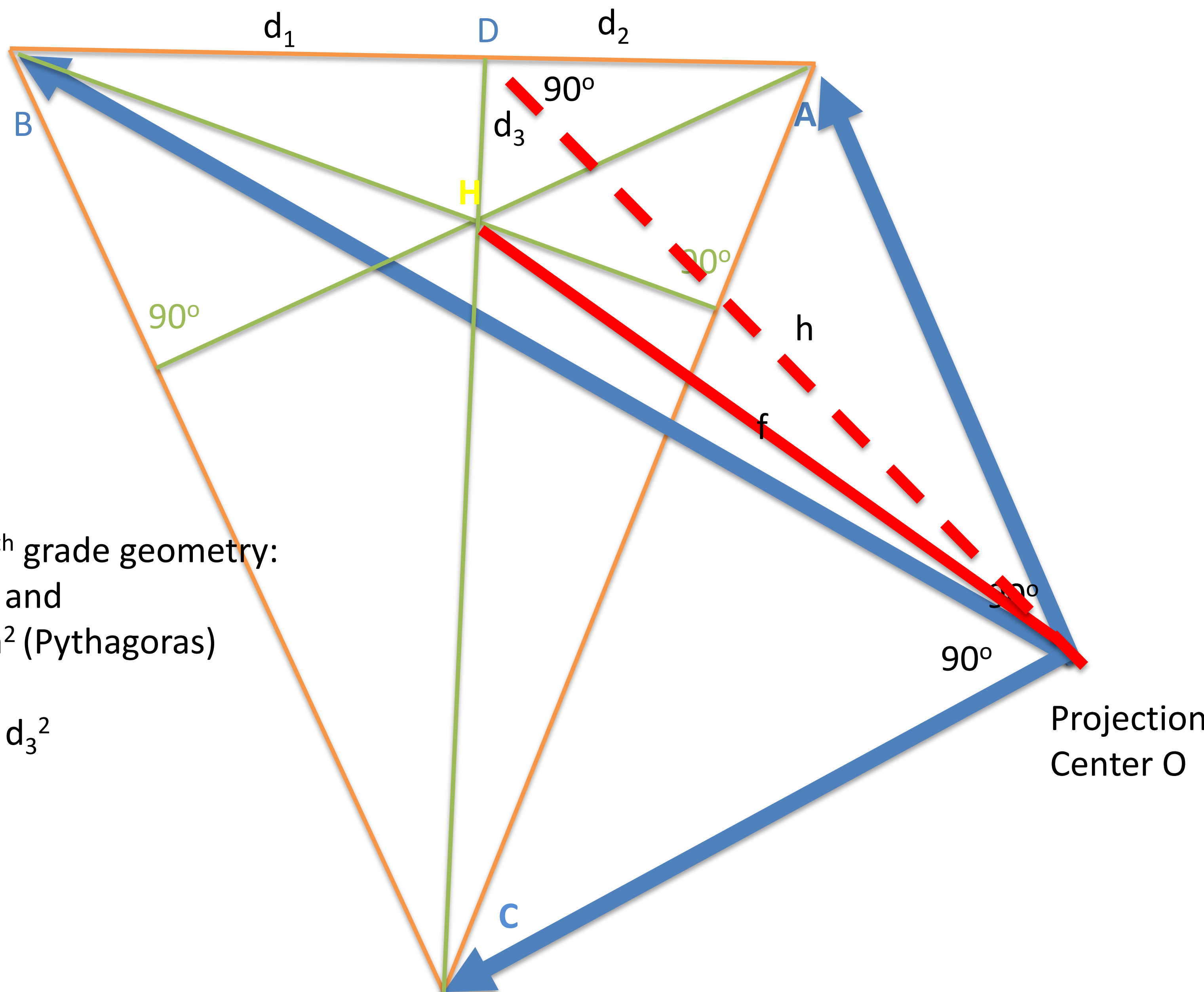
Let H be the orthocenter of the triangle ABC



Theorem from Euclidean Geometry:
If H is the orthocenter of ABC and all three angles AOB, BOC, and COA are right angles , the OH is perpendicular to ABC plane!

OH is the optical axis and ABC is the image plane, hence, H is the image center

We found the image center! What about the focal length (f=OH)?
Can it be computed from A,B, and C ?



Simple 9th grade geometry:
$h^2 = d_1 d_2$ and
$f^2 + d_3^2 = h^2$ (Pythagoras)
Hence
$f^2 = d_1 d_2 - d_3^2$

Three orthogonal vanishing points allow computation of focal length and image center !