

## TUTORIAL

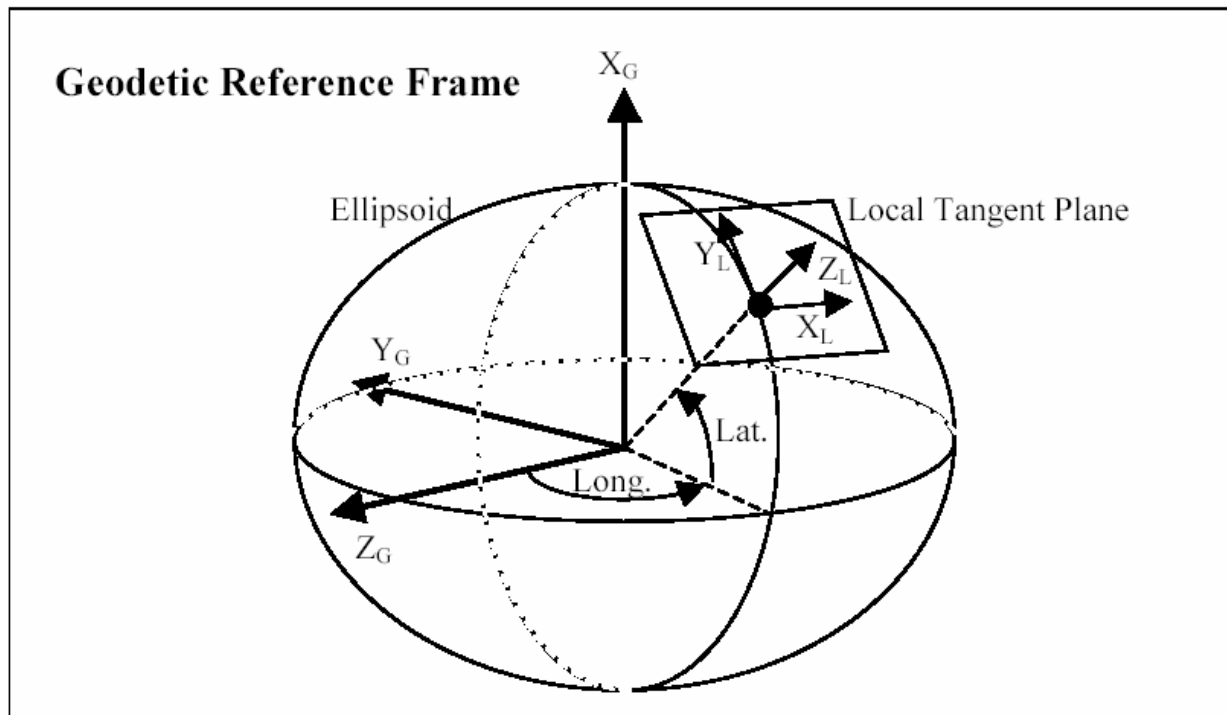
Many INS or IMU systems report the orientation of the sensor with the values Heading, Pitch, and Roll. However, most photogrammetric software, including OrthoEngine, expects the orientation of the image in terms of the values Omega, Phi, Kappa. Many users are confused by the difference. The inclination is to swap the three values around, changing signs as necessary, in order to put the rotations in the same order. This is not possible because the two sets of angles are measured in different reference systems.

### Image Frame to Local Tangent Plane

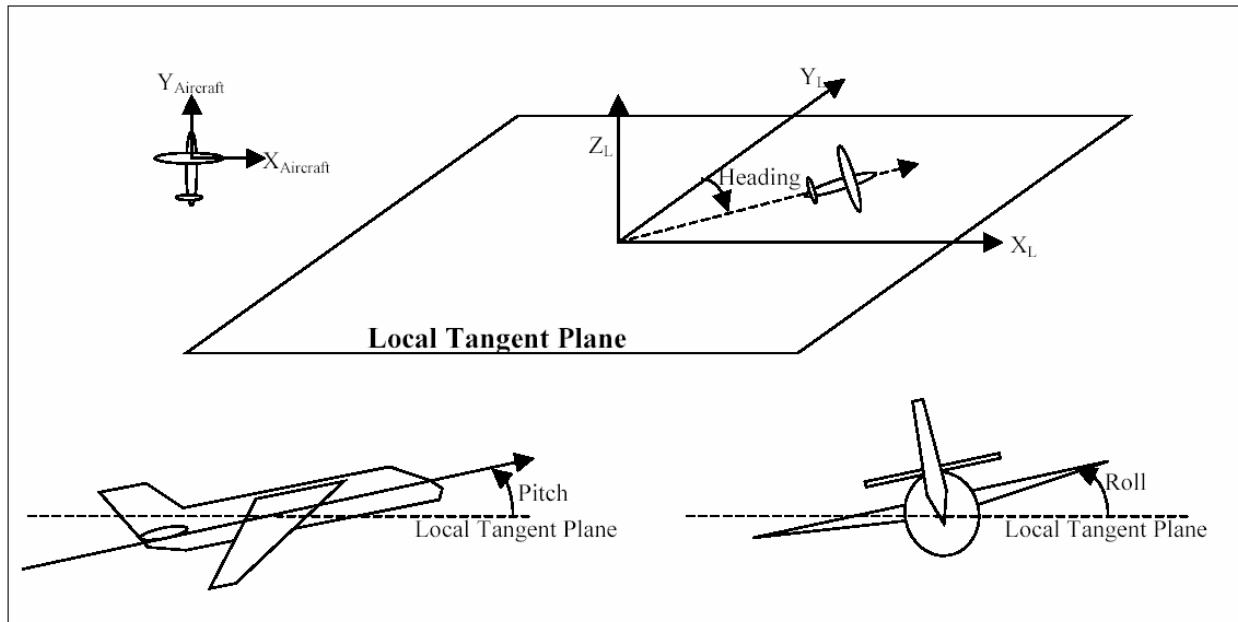
First, consider Heading, Pitch, and Roll (HPR). These are the three rotations that transform the image/sensor  $x, y, z$  axes, to a local horizontal plane. The rotations are generally applied in the order:

- Heading – Rotation about the Z axis
- Pitch – Rotation about the X axis
- Roll – Rotation about the Y axis

Heading, Pitch, Roll are the angles that relate the aircraft (and therefore the image) axes to the X, Y, Z axes of a local plane. This local plane is usually defined as a plane tangent to the geodetic ellipsoid, at the point of exposure. The North (+Y) axis of the local plane is the tangent to the local meridian on the ellipsoid, pointing toward the pole. The East (+X) axis of the local plane is the tangent to the geodetic ellipsoid, perpendicular to the local meridian. The Up (+Z) axis of the local plane is perpendicular to the surface of the geodetic ellipsoid.



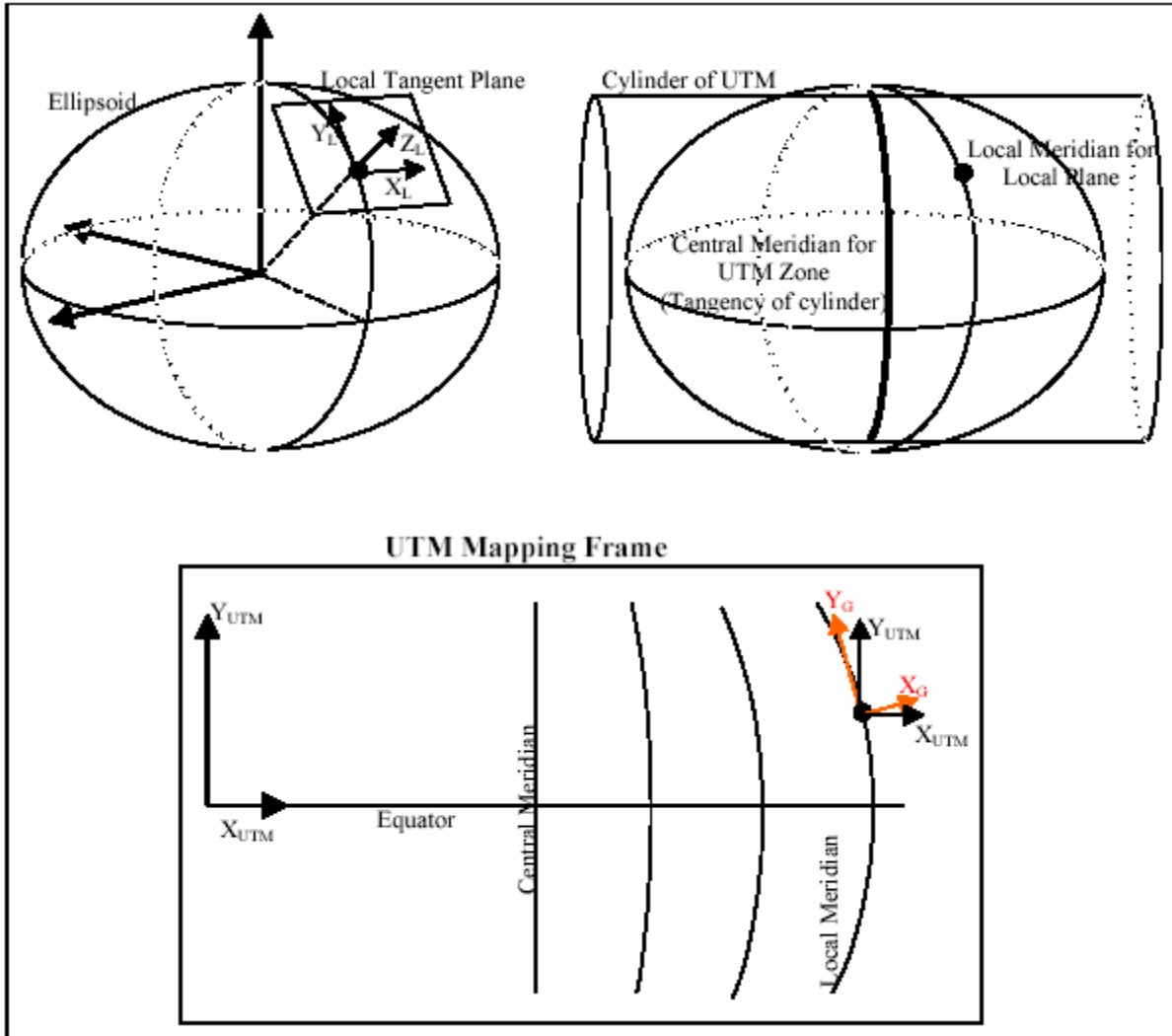
The Heading, Pitch, Roll rotations can be applied to transform the raw image to the correct location on the Local Tangent Plane. Aligning the image axes to the aircraft axes is usually quite trivial, and can involve swapping X and Y, changing the sign on one or more angles, and applying calibration offsets. After that, the Heading, Pitch, and Roll rotations are applied to map the raw image into the Local Tangent Plane.



The coordinates for the camera/sensor are usually given in what is referred to as an Earth Centred – Earth Fixed (ECEF) Geodetic Reference Frame. The X, Y, Z coordinates are measured from the centre of the ellipsoid, not on a flat plane. They may also be given in latitude, longitude, and height above ellipsoid. Most GPS/INS applications have traditionally been used for geodetic applications, where an ellipsoidal reference system is preferred. However, for photogrammetry applications, it is essential that we produce a flat image map, in a projection that can be readily used, and merged with other projected data. It is necessary to transform our Local Tangent Plane to a flat, projected mapping plane, such as UTM.

### Local Tangent Plane to UTM

Now we have images that have been corrected for heading, pitch, roll, but are mapped into a locally defined plane. The next step would be to transform our local plane images to a worldbased projection such as UTM. The Local Tangent Plane is defined with reference to the geodetic ellipsoid. It is tangent to the ellipsoid at the point of exposure. A UTM projection is formed by projecting the ellipsoidal earth onto a cylinder. The cylinder is placed transversely about the ellipsoid, and is tangent to the earth along a meridian of longitude. The meridian of tangency is called the central meridian. As we unwrap the cylinder to form a flat map, the central meridian will remain a vertical line along the UTM +Y axis. As you move away from the central meridian, other meridians appear increasingly warped, converging with the central meridian at the poles. The local meridian passing through the point of tangency of the Local Plane will not usually be coincident with the central meridian. This means that there will be differences between the X and Y axes of the Local Tangent Plane and a UTM projection. The Z axis will differ between the two systems everywhere, unless the Local Plane tangency point is exactly at the central meridian.



The reprojection between a Local Plane, referenced to ECEF locations, and a UTM projection, are complex geodetic calculations. At the moment, OrthoEngine and most other photogrammetric packages do not have this capability. The PCI OrthoEngine team is in the process of adding support for this transformation, so that Heading, Pitch, Roll data can be used directly.

## Compare to Omega, Phi, Kappa

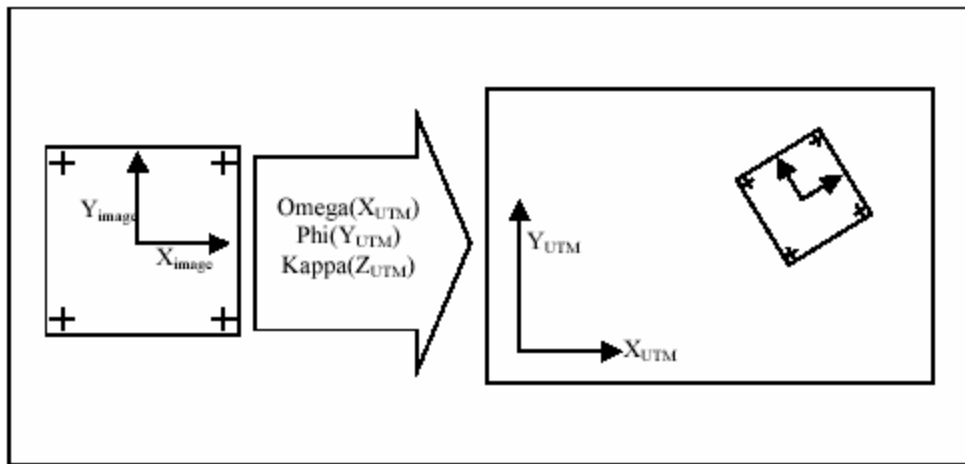
In the mean time, OrthoEngine supports the exterior orientation in the form Omega, Phi, Kappa. These three rotations are the transformation between the image reference system, and a flat, projected mapping plane, most often UTM. The three rotations are usually applied in the order:

Omega – Rotation about the X axis

Phi – Rotation about the Y axis

Kappa – Rotation about the Z axis

These angles will produce the same result as all of the above described transformations (based on Heading, Pitch, Roll), mapping the raw image directly into the UTM mapping plane. Since photogrammetrists are mainly concerned with obtaining georeferenced, flat maps, they normally work exclusively in Omega, Phi, Kappa angles.



Most GPS/INS sensor providers have developed post-processing software to perform the complex geodetic transformation from Heading, Pitch, Roll to Omega, Phi, Kappa. Please refer to POS/EO from Applanix, or your own INS/IMU provider for additional information.