

JSBSim Development Note

Coordinate Systems

There are at least five coordinate systems in use in JSBSim:

1. Structural
2. Body
3. Stability
4. Local
5. Inertial/Earth

Structural Axes

The structural frame is the frame defined by the manufacturer of the aircraft for fabrication reference. It is often defined with the X-axis directed aft, the Y-axis directed towards the right, and the Z-axis directed upwards. On some aircraft the centerline serves as the X-axis, with the origin of the coordinate system either at the tip of the aircraft nose, or somewhere out in front of it. Sometimes, as in the case of the space shuttle, the X-axis is parallel to, but offset from the aircraft centerline. The space shuttle centerline intersects the Z-axis at $Z=400$.

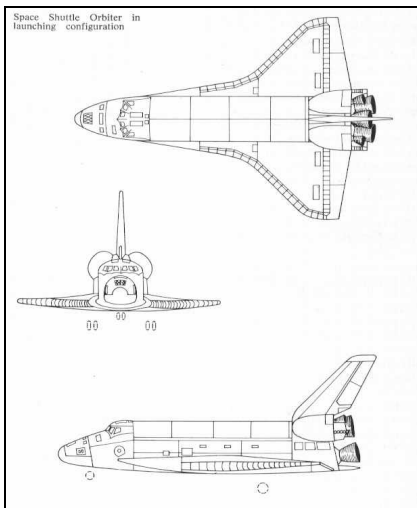


Figure 1

In JSBSim the structural frame is used to define the locations of physical objects or reference locations. For instance, the empty weight CG, the landing gear locations, pilot eye point location, fuel tank locations, and aerodynamic reference point are all located by structural coordinates. It doesn't really matter how the structural frame is set up, because JSBSim uses only distances between objects and the CG – not specific locations. JSBSim uses inches to specify locations in the structural frame.

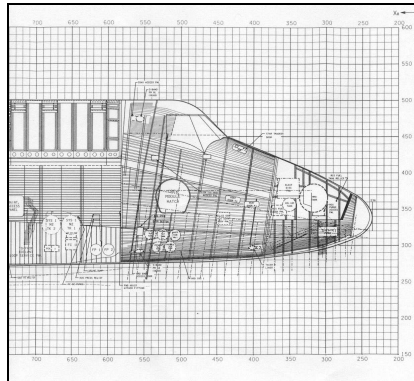


Figure 2

In figure 2, above, the shuttle coordinates can be seen.

Body and Stability Axes

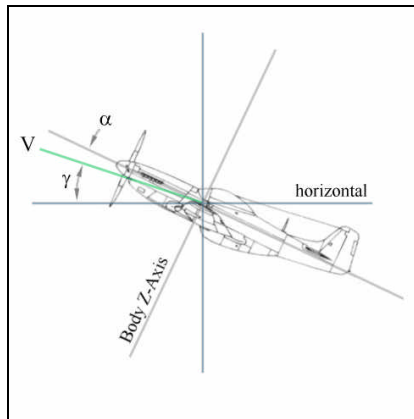


Figure 3

There are two axis systems that are used to relate the aircraft to its immediate surroundings in a meaningful way, and to describe its orientation and motion.

The *stability axes* are shown in Figure 3. The origin is at the center of gravity of the aircraft. The X_{stab} -Axis points into the relative wind, with Y_{stab} positive out the right wing, and Z_{stab} completing the set, positive downward. The stability axes are used to determine the forces and moments acting on the aircraft. If we know the angle of attack and the angle of sideslip for the aircraft, we can determine the forces acting on it. Once the forces are known, they need to be transformed to the *body axes*. In JSBSim this is done with the `FGState::GetTs2b(float alpha, float beta)` function call.

The body axes are fixed to the aircraft with the origin at the aircraft center of gravity, the X_{body} -Axis positive forward out through the nose, Y_{body}

positive out the right side, and Z_{body} positive downwards. Once the forces have been transformed from the stability axes to the body axes we can integrate their effects and determine the acceleration and velocity, as well as a new position and the orientation of the aircraft relative to the world. The body axes are illustrated on the left side in figure 3.

The Local Reference Frame

The local frame can most easily be pictured this way. Imagine a line drawn from the aircraft to the center of the earth. This defines the Z_{local} -Axis, with the caveat that the origin is at the surface of the earth, and it is positive towards the earth center. Now, imagine a plane tangent to the earth surface at the point where the Z_{local} axis meets the earth surface. The X_{local} -Axis is located in this plane, and pointing north. The Y_{local} -Axis is located in this plane and points east. If the aircraft is level with the local terrain and is pointed north, the body frame of the aircraft is oriented parallel to the local frame and the transformation matrix to go between the two frames is an identity matrix.

The Earth Frame

The earth frame is attached to the earth but does not rotate with it – it is an inertial frame. The origin is at the center of the earth, with the Z-Axis pointing out the North Pole, the X-Axis passing through the equator at the “Zero Meridian”, and the Y-Axis as needed.