1 Requirement for Datums

Use of datums in product definition is required in order to specify part features that are used as a basis for functional relationship with other features on the part. Where design or manufacturing intent will be substantially affected by the relationship of part features to part orientation, datums must be defined. If the relationships of part features are not important to function or other requirements, it may not be necessary to use datums. However, this is not usually the case. When datums are not defined, the designer is depending on the manufacturing and quality departments to use good discretion in regards to how the part is intended to function.

2 Datums and Six Degrees of Freedom

It is helpful to think of defining datums based on how the part inspector will set up the part for inspection such that his results are meaningful to part function. Defining datums establishes a coordinate system from which the measurements are taken. In order to inspect the part, one must first immobilize the part in order that measurements are taken relative to pre-defined features (datums). References to the established datums are made within GD&T feature control frames, which control tolerances of Location, Profile, Orientation, and Runout for part features. There can be one or multiple datum reference systems established for a given part. The tolerances within the control frames are determined and specified after careful consideration of part function, quality, and manufacturing capability.

Here, we introduce the basic principle of locating a part. To locate a part, it must be constrained relative to six degrees of freedom (DOF). When all six DOFs of a part are constrained, it is a complete part location. This is referred to as the six-point locating principle.

For a rigid part in space, there are six degrees of freedom defining the position and orientation of the part. There are three linear motions (along x axis, y axis, and z axis) X, Y, and Z, and three rotational motions (around x axis, y axis, and z axis) α_x, α_y, and α_z. Figure 2-1 illustrates the six DOFs with respect to a coordinate system.

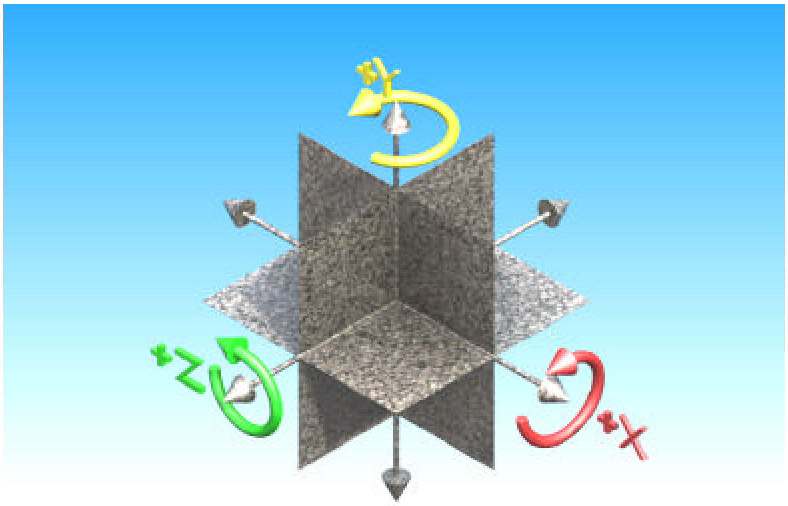

Figure 2-1. Illustration of coordinate system showing 6 degrees of freedom.
(Translate along X, Y, and Z and Rotate about X, Y, and Z)

To completely immobilize the part and to establish a complete datum reference frame, all six DOFs must be constrained. A common method of constraining the DOFs is to establish 6 contact points. The six contact points are contained within three mutually perpendicular planes XZ, YZ, and XY as illustrated with six pins in figure 2-2. Three points on plane XZ establish the primary datum and constrain 3 DOFs (translation along Y, rotation about X, and rotation about Z). Two points on plane YZ establish a secondary datum and constrain 2 DOFs (translation along X, and rotation about Y). One point on plane XY establishes the tertiary datum and constrains 1 DOF (translation along Z). This is called the 3-2-1 locating principle. Figures 2-3 through.2-5 illustrate a machined block part being constrained with respect to the six DOFs -- in sequence by order of datum precedence.

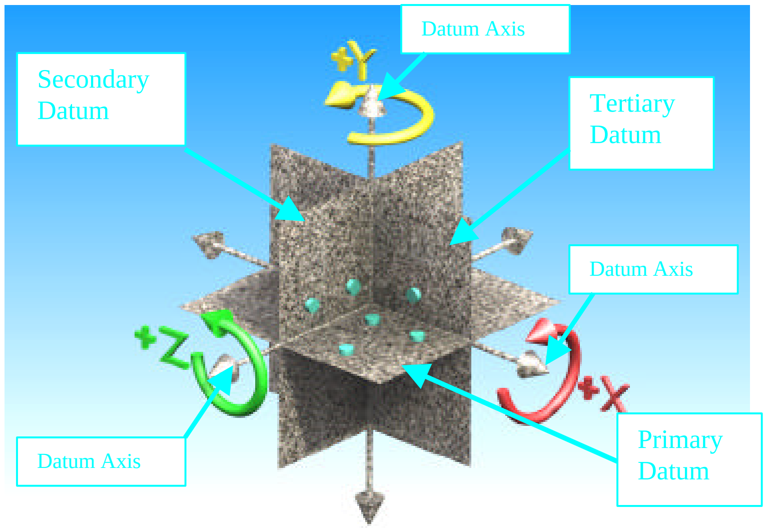

Figure 2-2. Illustration of coordinate system showing 6 contact points for 3-2-1 location.
(3 points on plane XZ, 2 points on plane YZ, and 1 point on plane XY)
This coordinate system can now be considered a datum reference frame with three mutually perpendicular (90 degree) datum planes and three datum axis.

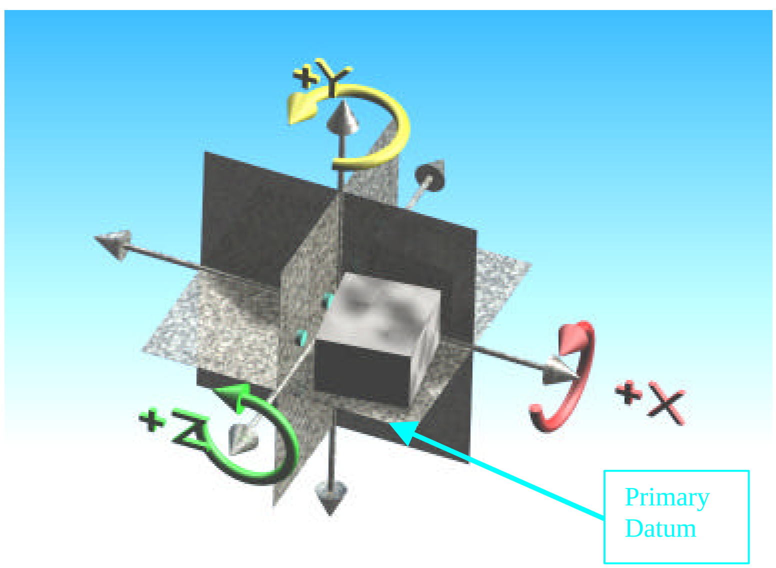

Figure 2-3. Illustration of coordinate system showing part with contact on primary datum.
(3 points on plane XZ)
Part is constrained in 3 DOFs (Translation along Y, rotation about X and Z)
Part is still free to move in 3 DOFs (Translation along X and Z, rotation about Y)

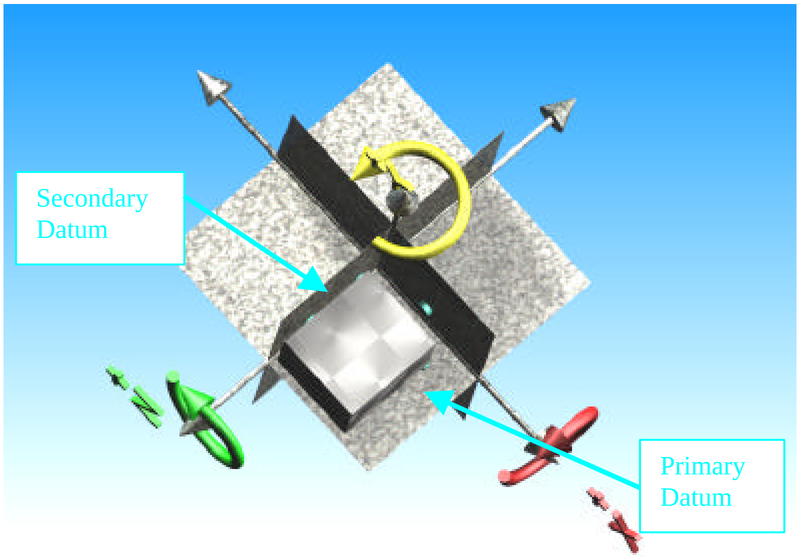

Figure 2-4. Illustration of coordinate system showing part with contact on primary datum.
(3 points on plane XZ)
Plus part is in contact with secondary datum.
(2 points on plane YZ)
Part is constrained in 5 DOFs (Translation along X and Y, rotation about X, Y, Z)
Part is still free to move in 1 DOF (Translation along Z)

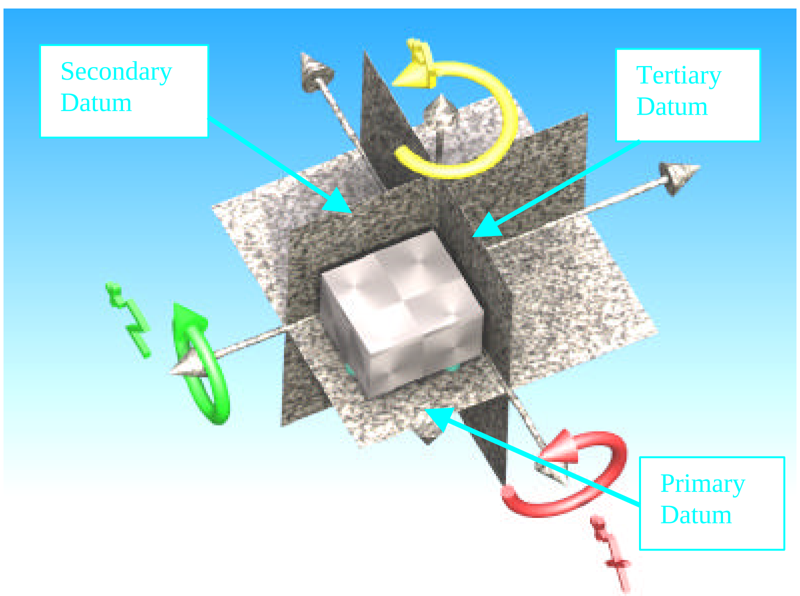

Figure 2-5. Illustration of coordinate system showing part with contact on primary datum.
(3 points on plane XZ)
Plus part is in contact with secondary datum.
(2 points on plane YZ)
Plus part is in contact with tertiary datum.
(1 point on plane XY)
Part is fully constrained in 6 DOFs (Translation along X, Y, Z, & rotation about X, Y, Z)

A variation of the 6-point method is used for long cylindrical parts and is illustrated in figure 2-7. The first four of the six contact points are in two planes that form a "V" as illustrated with four pins on the V-block in figure 2-6. These four points establish the primary datum. This datum has its center as the Z-axis, through which the two mutually perpendicular planes XZ and YZ intersect. These four points constrain 4 DOFs (translation along X and Y, & rotation about X, and Y). One point on plane XY establishes a secondary datum and constrains 1 DOF (translation along Z). The last point on a plane parallel to plane XY (or on plane XY) establishes the tertiary datum and constrains 1 DOF (rotation about Z). Figures 2-8 through 2-10 illustrate a long cylindrical part with one hole in the near face. This cylindrical part is being constrained with respect to the six DOFs in sequence by order of datum precedence.

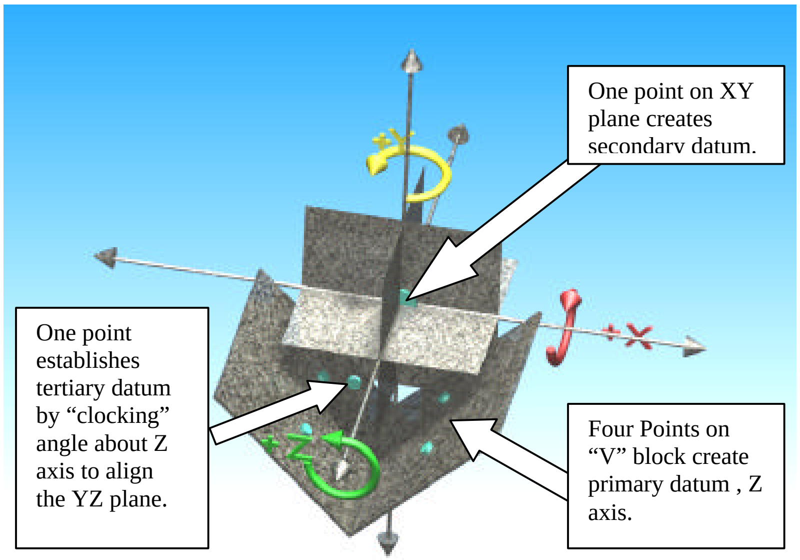

Figure 2-7. Illustration of coordinate system showing 6 contact points for locating a cylindrical part. (4 points on v-block, 1 point on plane XY, and 1 point on a plane parallel to plane XY) The datum reference frame, like in the other example, is three mutually perpendicular (90 degree) datum planes and three datum axis.

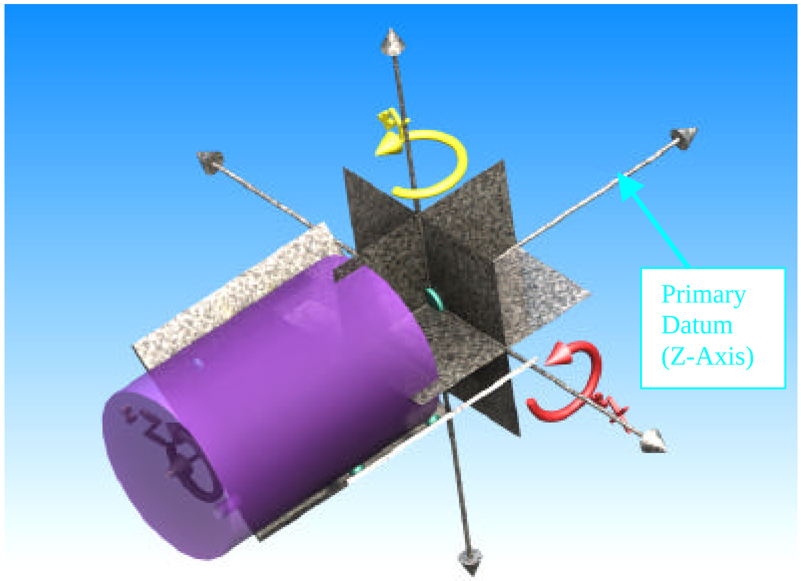

Figure 2-8. Illustration of coordinate system showing part with contact on primary datum.
(4 points on v-block, establishing Z-axis)
Part is constrained in 4 DOFs (Translation along X and Y, rotation about X and Z)
Part is still free to move in 2 DOFs (Translation along Z, rotation about Z)

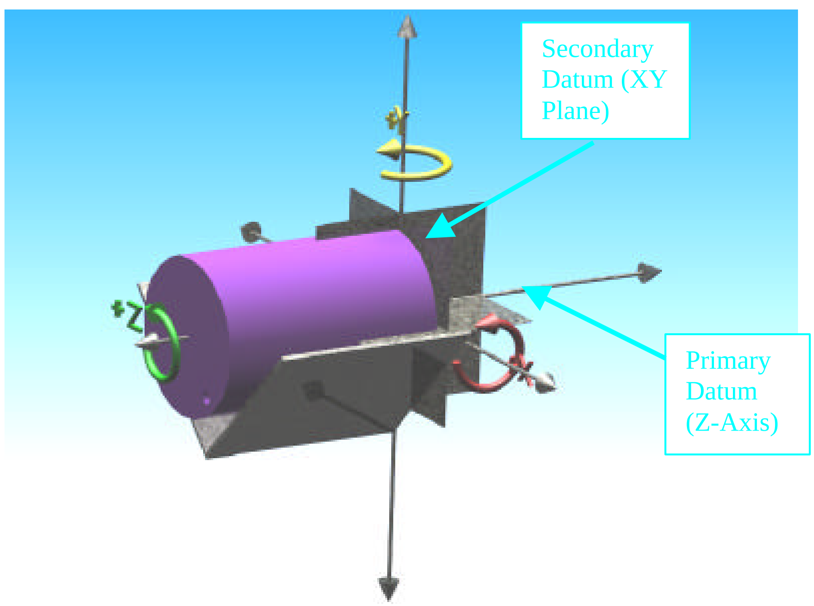

Figure 2-9. Illustration of coordinate system showing part with contact on primary datum.
(4 points on v-block, establishing Z-axis)
Plus part is in contact with secondary datum.
(1 point on plane XY)
Part is constrained in 5 DOFs (Translation along X, Y, and Z, rotation about X and Z)
Part is still free to move in 1 DOF (Rotation about Z)

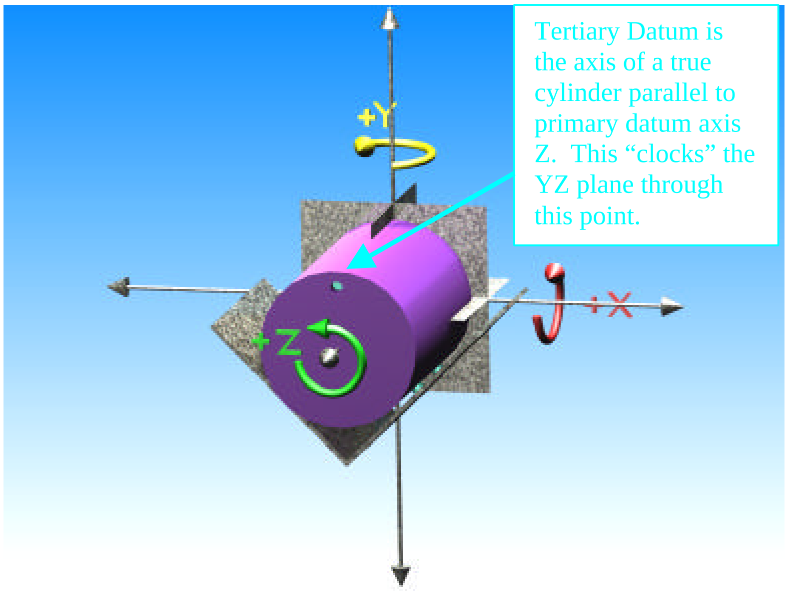

Figure 2-10. Illustration of coordinate system showing part with contact on primary datum.
(4 points on v-block, establishing Z-axis)
Plus part is in contact with secondary datum.
(1 point on plane XY)
Plus part is in contact with tertiary datum.
(1 point on an axis of a cylinder parallel to Z axis)
Part is fully constrained in 6 DOFs (Translation along X, Y, Z, & rotation about X, Y, Z)

3 Application of Datums

Note that the simplified illustrations showing six contact points are used to explain the concept of six DOFs. In actual use, we normally define datums through annotation of the datum feature(s). Likewise, the product is typically manufactured and inspected through utilization of simulated datum features. Datums are simulated through practical means, using machine tables, surface plates, fixture surfaces, pin gages, etc. -- of such high quality that they are considered true references. Pins, as illustrated, are not necessarily defined or used. As required, datum targets or other datum annotation techniques may be employed. Also, the part may be manufactured using common fixture techniques including locating pins in order to best accomplish proper work holding. Datums may be features of size, offset, equalizing, complex feature, etc. Numerous examples of various datum applications can be found in ASME Y14.5 and associated published handbooks. The reader should refer to those publications for application guidelines.

Design dataset that clearly communicate design intent are the most important argument for the use of datums. Lack of ambiguity will prevent costly design misinterpretations. With this in mind, the following standard practices should be considered in the datum selection process.

1. Datum features are chosen based on geometric relationships to toleranced features and to the requirements of the design.

2. Features corresponding to mating features of mating parts should be selected as datum features (in order to facilitate tolerance calculations and ensure proper part assembly). However, a datum feature should be accessible on the part and be of sufficient size to permit its use. For example, as a rule of thumb a cylindrical feature should have a depth to diameter ratio of 3-to-1 in order for the cylinder to create a stable axis datum.
3. Datum features must be readily discernible on the part. In the case of symmetrical parts or parts with identical features, physical identification (by design) of the datum feature on the part may be necessary.
4. To enable readily obtainable measurements, a datum needs to be accessible during manufacturing. Definitely do not use a point in space that is not defined from part features.
5. Where required to avoid ambiguity of design requirements, specify datums as required for clarity. If necessary, specific or general notations may be used where GD&T feature control frames cannot. For example, in the case of a part design using plus and minus or general profile tolerances, the design may include defined datum features along with a general note specifying the datum system to be used unless otherwise specified.
6. Consider the precision of the datum feature(s). As required, additional geometric control may need to be applied to the datum feature in order that the feature(s) exhibit the desired accuracy. In the case that it is not practical to control the entire datum feature, consider using datum targets or a partial feature as the datum.