<u>**OGP Knowledge Document**</u>

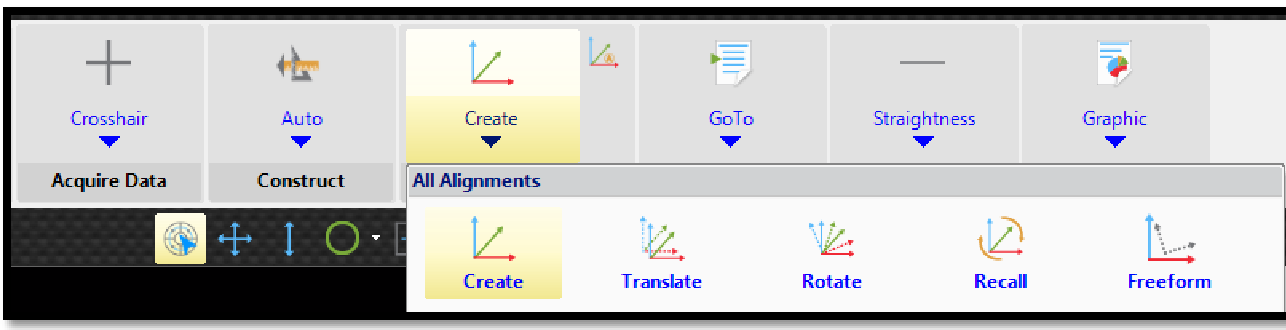
<u>**Feature Alignment**</u>

Overview:

Feature Alignment is the most commonly used Alignment Type in ZONE3. A Feature Alignment is defined by how it constrains the 6 degrees of freedom based on the order of up to 3 different features.

About Alignment:

In 3D measurement, alignment is the process of locating a part on the stage and establishing a coordinate system, which all following measurements will be based on. A proper alignment will ensure that all the measurements are taken in the correct location on the part, by accounting for variation in position and orientation of each part as it is inspected. An alignment can be created in ZONE3 by selecting Create from the Alignment tab.



Once in the alignment step, a Feature Alignment can be chosen from the dropdown menu under Alignment Type. Feature Alignment will be the default Alignment type.

Degrees of Freedom

In ZONE3, part position is defined by 6 degrees of freedom (DOF): 3 translations and 3 rotations. These include translation in X, Y, and Z, and rotation about the X, Y, and Z axes. The following graphic (Figure 1) illustrates these degrees of freedom, with the straight arrows representing translations and the curved arrows representing rotations.

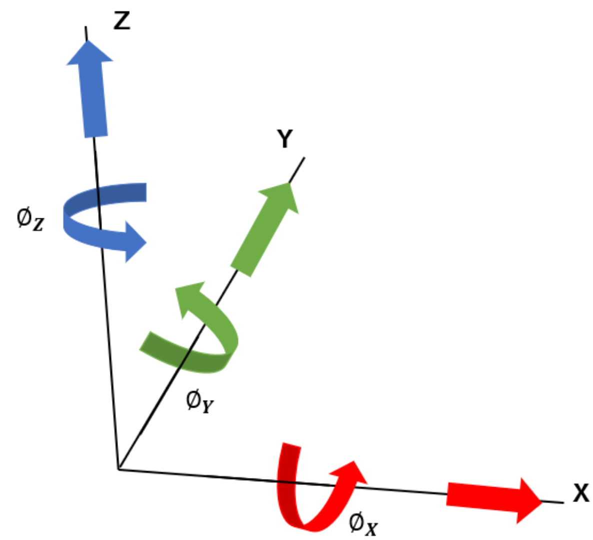
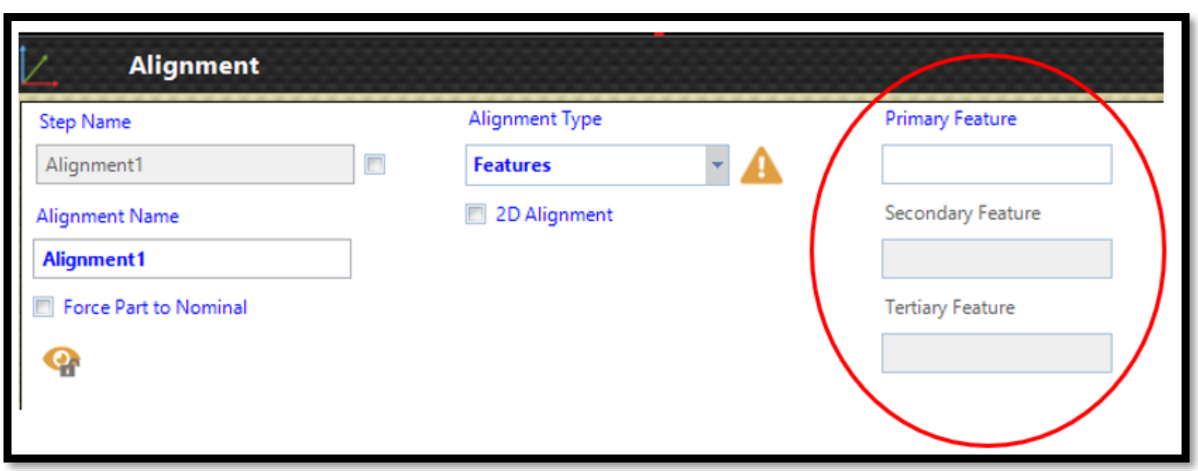


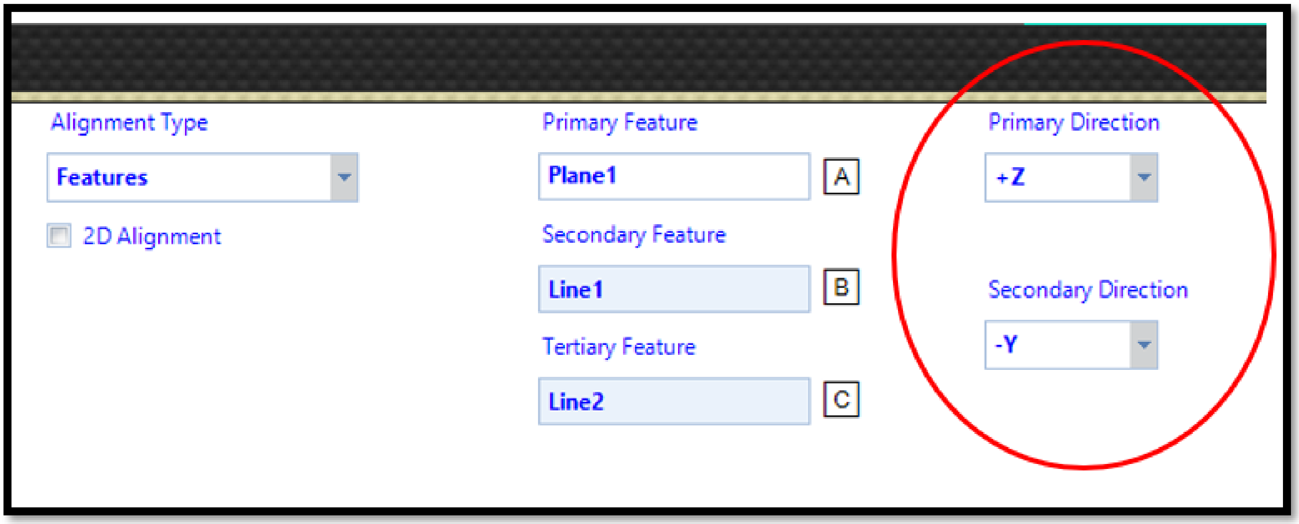
Figure 1

An alignment that is fully constrained will have all 6 DOF locked in, meaning that it is not free to move or rotate in any direction. Ideally a measurement routine will use a fully constrained alignment.

In ZONE3, Feature Alignment constrains alignment to features based on their order. When creating a Feature Alignment in ZONE3, there is the option to pick primary, secondary, and/or tertiary feature(s). The type of feature chosen will determine which DOF are locked in. The primary feature will lock in as many degrees of freedom as the selected feature type can define. The secondary feature will lock in what it can from the remaining DOF. The tertiary feature will then lock in what it can from what remains.



Feature Alignment in ZONE3 follows the ASME Y14.5M-1994 standard. When building an alignment, the constraint is based on the feature order, and the current axis orientation is prioritized to reduce rotation. Rotation can also be chosen manually by selecting a Primary and Secondary Direction of Axis from the dropdown menus.



<u>Feature Alignment Example</u>

The following feature alignment example is based on the ZONE3 training part and involves selecting a primary, secondary, and tertiary feature to constrain the alignment. In this example, the features used are the top plane, front edge line, and the left edge line of the block (shown in Figure 2). These features are selected for this part because they are stable features and together will lock in all 6 DOF.

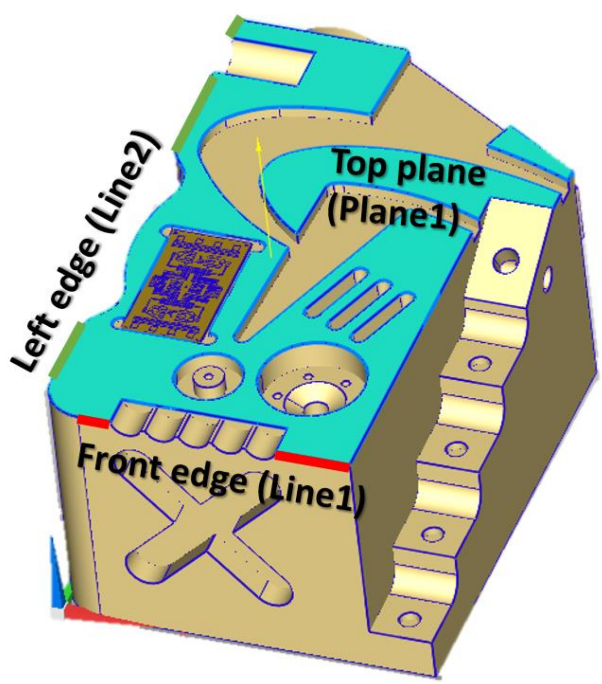
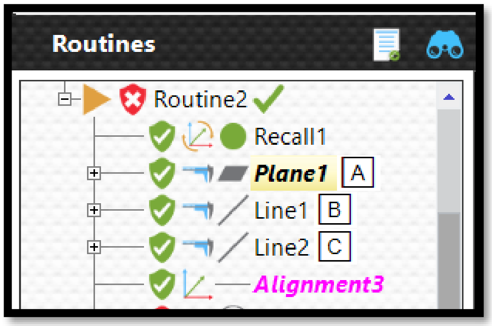
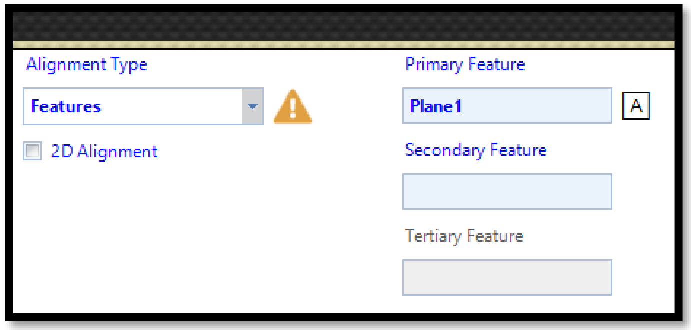


Figure 2

Primary Feature

For this example, the top plane of the part is chosen as the primary feature. Within the alignment step, the primary feature is chosen by selecting the feature in the routine tree.





As the primary feature, the plane will lock in 3 DOF; translation in Z and rotation about the X and Y axes. This means that the coordinate system is no longer able to move up and down in Z because the plane is set as the Z location (shown in Figure 4). The coordinate system is also prevented from rotating about the X and Y axes because any points on the Z plane can only rotate about the Z axis and still be on the plane. The following DOF graphic (Figure 3) illustrates which DOF are locked in from the plane, with the circled DOF representing what the plane is locking in and the red, green, and blue arrows representing the total DOF that are locked in.

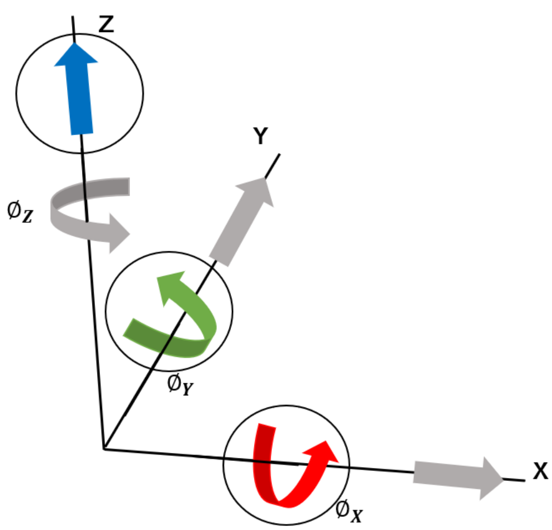


Figure 3

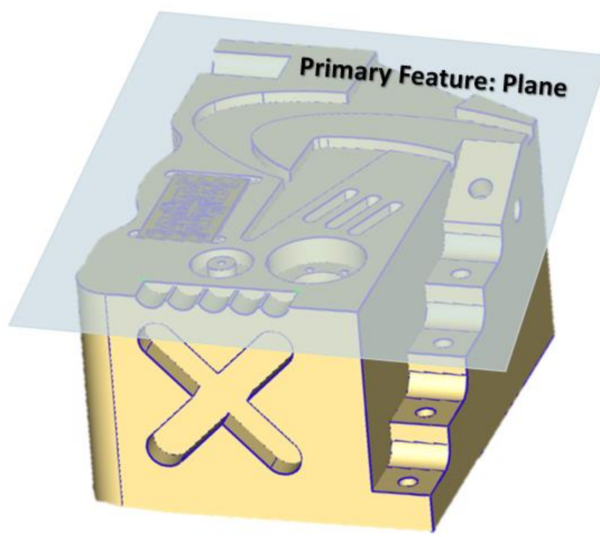


Figure 4

Once the plane is selected as the primary feature, a translucent coordinate system will appear on the CAD model at the location of the plane (Figure 5). This is where the new coordinate system would be if the alignment step was saved with only the primary feature selected. Since not all DOF are locked in, the translucent coordinate system is portrayed as moving in the remaining DOF, translating in X and Y and rotating about the Z axis. The current coordinate system is also shown on the model to show that the new alignment is still being drafted.

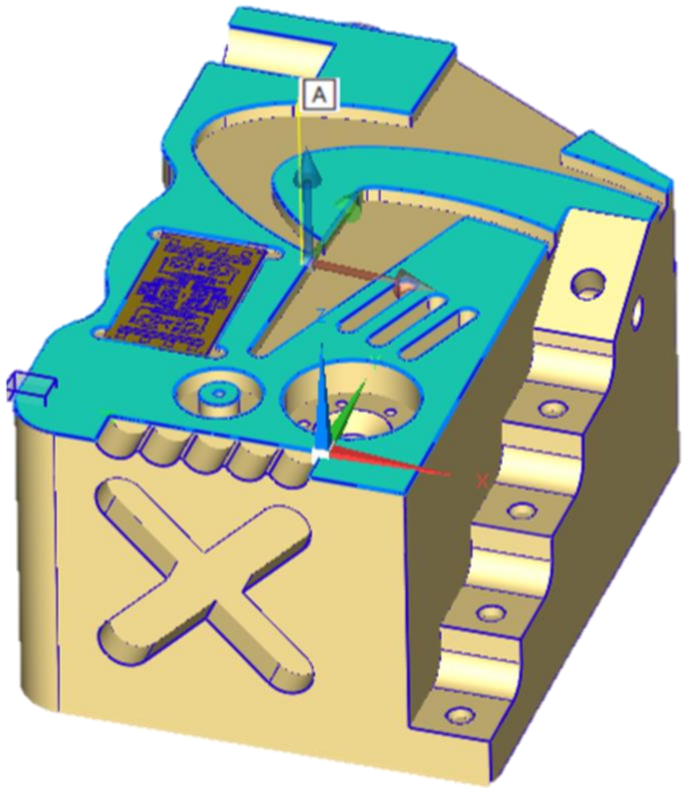
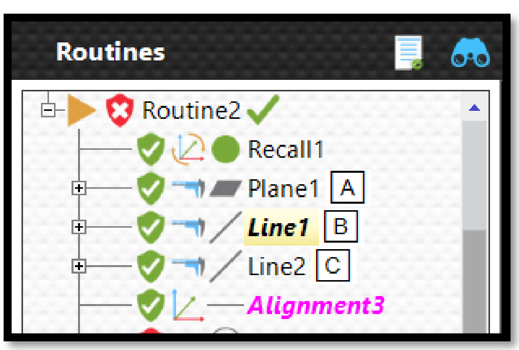
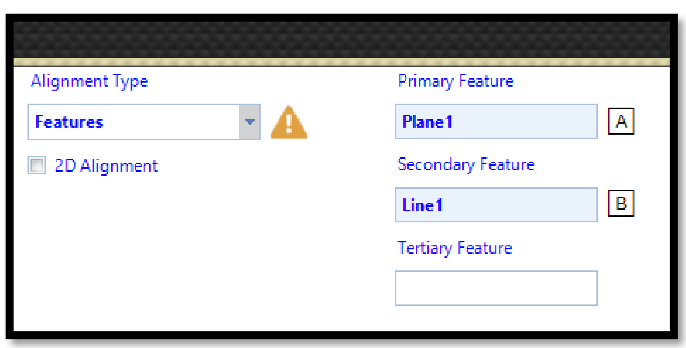


Figure 5

Secondary Feature

The secondary feature is chosen to be one of the two lines, the front edge or the left edge. Since they are the same feature type, selecting either of these two features will lock in 2 of the remaining DOF and the order of the 2 lines does not matter. In this example, the front edge line is chosen as the secondary feature. Within the alignment step, the secondary feature is chosen by selecting the feature in the routine tree.





This line will lock in 2 DOF, translation in Y and rotation about the Z axis. This means that the coordinate system is no longer able to move in Y because the line is set as the Y location (shown in Figure 7). The coordinate system is also prevented from rotating about the Z axis because the line is setting the Y-X orientation. The following DOF graphic (Figure 6) illustrates which DOF are locked in from both the plane and line, with the circled DOF representing the DOF that the line locks in and the red, green, and blue arrows representing the total DOF that are locked in.

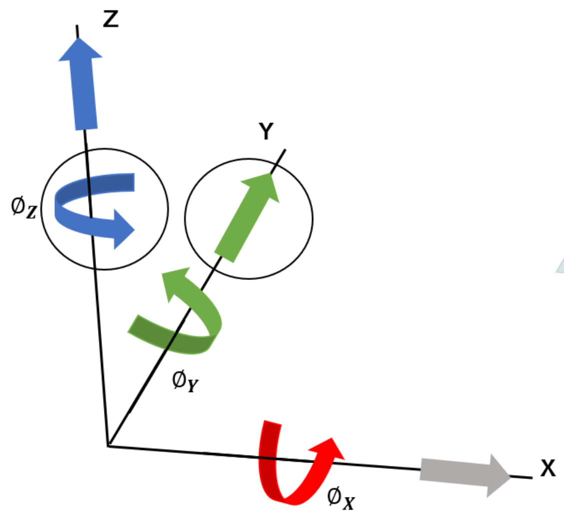


Figure 6

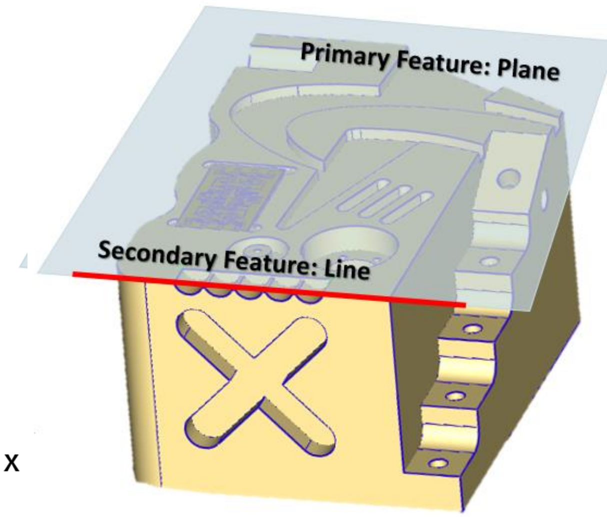


Figure 7

Once the line is selected as the secondary feature, the translucent coordinate system will move in Y to be at the location of the line (Figure 8). Since translation in X is the only DOF not yet locked in, the translucent coordinate system is portrayed as moving in X.

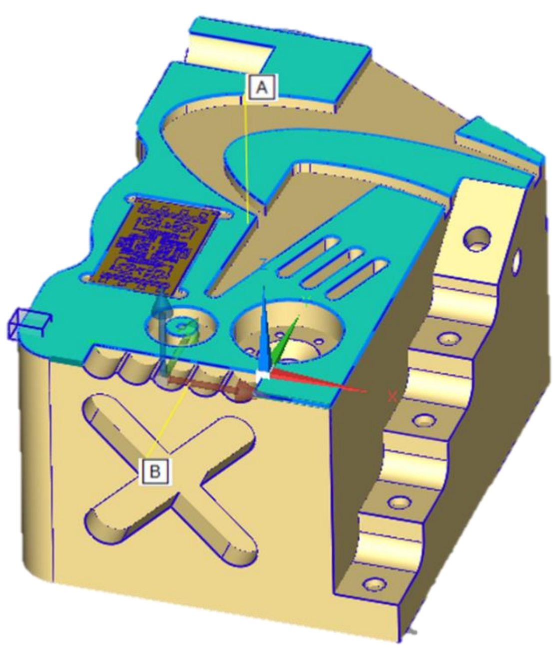
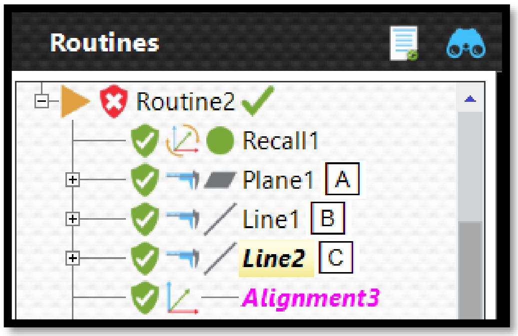
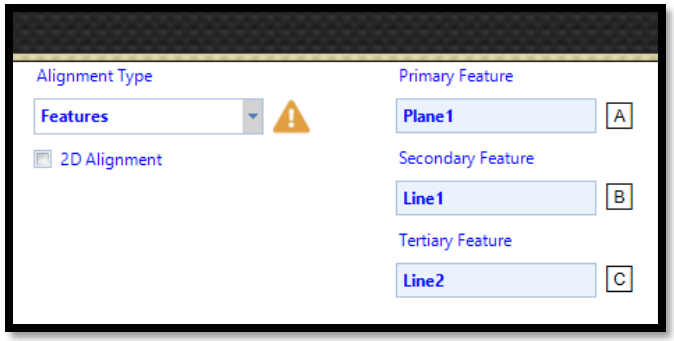


Figure 8

Tertiary Feature

The second line, the left edge of the part, is chosen as the tertiary feature. Within the alignment step, the tertiary feature is chosen by selecting the feature in the routine tree.





This line will lock in the final DOF, translation in X. This means that the coordinate system is no longer able to move in X because the line is set as the X location (shown in Figure 10). After the tertiary feature is selected, all six DOF are locked in, making this a fully constrained alignment. The DOF graphic (Figure 9) has all six DOF in color to reflect this. The circled DOF represents what the tertiary feature is locking in. With the fully constrained alignment, the coordinate system is no longer free to move or rotate, and its location and orientation are fully locked in.

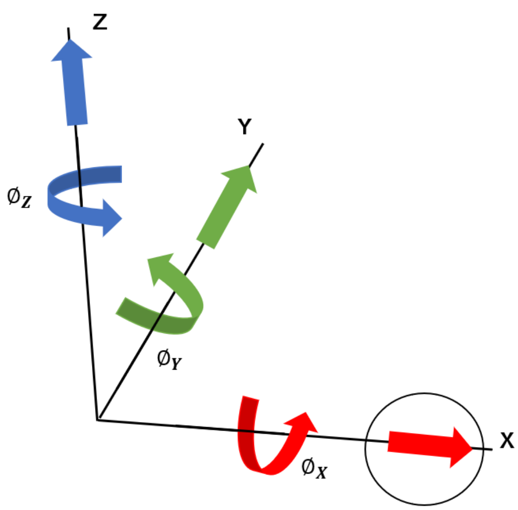


Figure 9

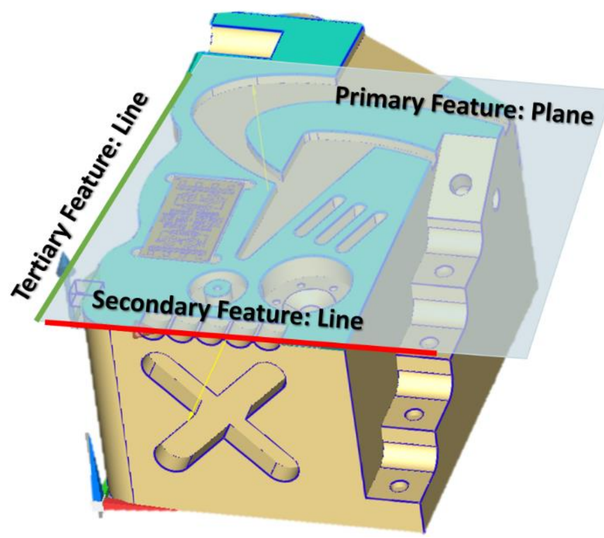


Figure 10

Once the second line is selected as the tertiary feature, the translucent coordinate system will move in X to be at the location of the line and is now at the XYZ location set by the 3 features. Since all 6 DOF are now locked in, the translucent coordinate system has stopped moving (shown in Figure 11).

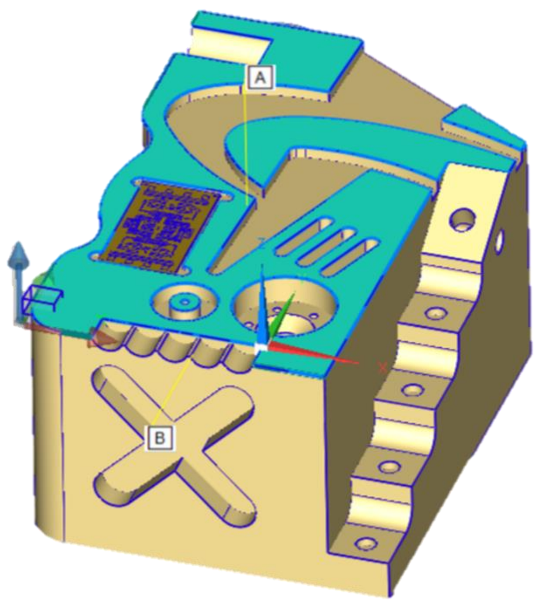


Figure 11

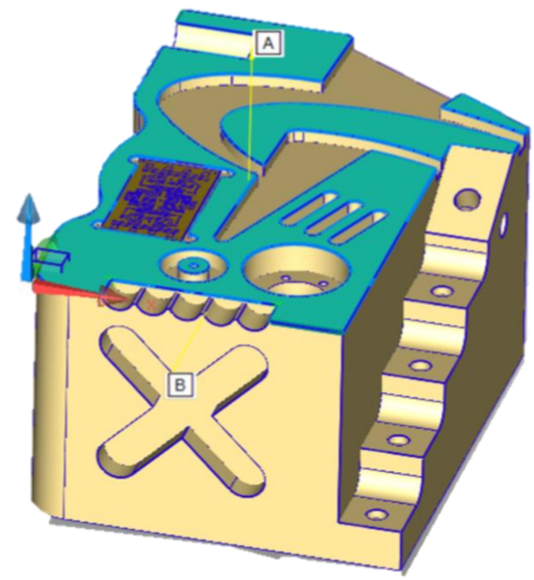


Figure 12

After saving the alignment step, the coordinate system will move to where the translucent coordinate system was (Figure 12). The coordinate system is now fully aligned, and any subsequent measurements will be based off this coordinate system.

Feature Types and Constraint

The plane, line, line alignment example is used for the ZONE3 training part because these are stable features and a good example. In practice, different combinations of features may be selected to constrain the alignment. Different feature types will constrain different DOF (shown in Table 1). Table 1 describes the constraint of some of the common primary features used in Feature Alignment.

When constraining DOF, features are reduced to their simple forms; Point as Primary, Line as Primary, or Plane as Primary. Point as Primary may be a point feature or a point reducible feature and Line as Primary is a feature that has axes. Plane as Primary is recommended; this may be a plane feature or a line feature as a linear element of a plane. In Table 1, X, Y, and Z represent translation in the three axes and u, v, and w represent rotation about the three axes. Additional information about feature types and constraint can be found in Appendix A.

Table 1: Common Primary Feature Types

Feature Type	Reducibility	Free DOF	Constrained DOF
Point	Point as Primary	u,v,w	X,Y,Z
Line	linear element of Plane as Primary	Z,w	X,Y,u,v
Plane	Plane as Primary	X,Y,w	Z,u,v
Circle	point reducible (center point)	u,v,w	X,Y,Z
Cylinder	point reducible (center point) and line reducible (axis)	Z,w	X,Y,u,v

Appendix A:

Table 2: Feature Reducibility in ZONE3

Feature Type	Point reducible	Line reducible	Plane reducible
Arc / Circle	Yes – center point	No	No
Cone	Yes – apex (vertex)	Yes – axis	No
Cylinder	Yes – center point	Yes – axis	No
Line	No	Yes	No
Plane	No	No	Yes
Point	Yes	No	No
ClosedSlot2D	Yes – center point	Yes – centerline axis	No
Sphere	Yes – center point	No	No

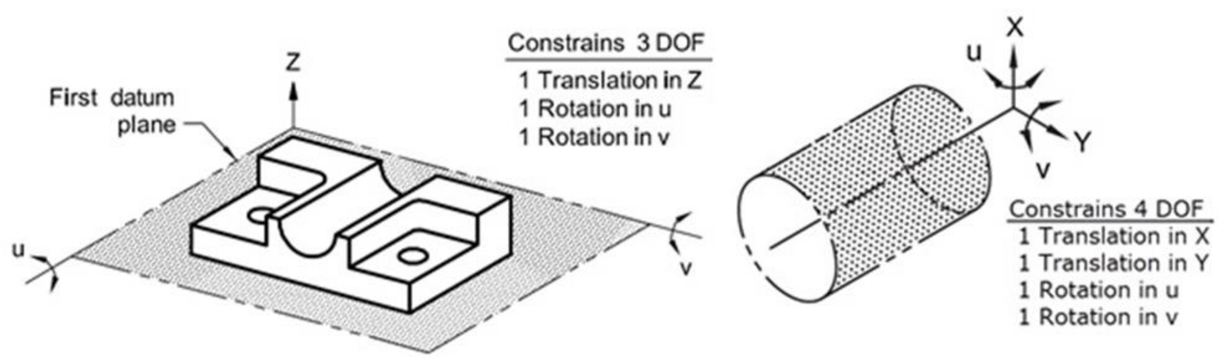


Figure 13: Graphic examples of constraint by primary features, a plane and a cylinder.

Table 3: Symbols for Datum Tables

Symbol	Description
A	primary datum
B	secondary datum
C	tertiary datum
PT	point
AX	axis
PL	plane
{LI ...}	line through ...
{LI ... : ... }	line through ... such that ... is true
$\neq$	not coincidental with
$\subset$	contained within
$\not\subset$	not contained within
//	parallel with
$\perp$	perpendicular to
$\wedge$	logical AND
$\vee$	logical OR (one or the other, or both)
$\neg$	logical NOT
$\cap$	intersection
x, y, z	position in a cartesian coordinate system
u, v, w	rotation about x, y, z axis, respectively; yaw, pitch, roll, respectively
γ_z	angle relative to datum axis z
r	spherical radius: $\sqrt{x^2 + y^2 + z^2}$
P_z	cylindrical radius: $\sqrt{x^2 + y^2}$
—	no entry (e.g., not applicable, none)

Table 4: Point as Primary Datum

Case	Datums			Free xfrms	Invariants	Validity Conditions
	A	B	C			
1.1	PT	—	—	u, v, w	r	—
1.2	PT	PT	—	w	ρ_z, z, γ_z	A $\neq$ B
1.3	PT	PT	PT	—	all	(A $\neq$ B) $\wedge$ (C $\not\subset$ {LI A-B})
1.4	PT	PT	AX	—	all	(A $\neq$ B) $\wedge$ (C $\neq$ {LI A-B})
1.5	PT	PT	PL	—	all	(A $\neq$ B) $\wedge$ $\neg$ (C $\perp$ {LI A-B})
1.6	PT	AX	—	—	all	A $\not\subset$ B
1.7	PT	AX	—	w	ρ_z, z, γ_z	A $\subset$ B
1.8	PT	AX	PT	—	all	(A $\subset$ B) $\wedge$ (C $\not\subset$ B)
1.9	PT	AX	AX	—	all	(A $\subset$ B) $\wedge$ (B $\neq$ C)
1.10	PT	AX	PL	—	all	(A $\subset$ B) $\wedge$ $\neg$ (B $\perp$ C)
1.11	PT	PL	—	w	ρ_z, z, γ_z	—
1.12	PT	PL	PT	—	all	C $\not\subset$ {LI A: LI $\perp$ B}
1.13	PT	PL	AX	—	all	C $\neq$ {LI A: LI $\perp$ B}
1.14	PT	PL	PL	—	all	$\neg$ (C // B)

Table 5: Line as Primary Datum

Case	Datums A	Datums B	Datums C	Free xfrms	Invariants	Validity Conditions
2.1	AX	—	—	z, w	ρ_z, γ_z	—
2.2	AX	PT	—	—	all	$B \not\subset A$
2.3	AX	PT	—	w	ρ_z, z, γ_z	$B \subset A$
2.4	AX	PT	PT	—	all	$(B \subset A) \wedge (C \not\subset A)$
2.5	AX	PT	AX	—	all	$(B \subset A) \wedge (A \neq C)$
2.6	AX	PT	PL	—	all	$(B \subset A) \wedge \neg (A \perp C)$
2.7	AX	AX	—	—	all	$(A \neq B) \wedge \neg (A // B)$
2.8	AX	AX	—	z	x, y, u, v, w	$(A \neq B) \wedge (A // B)$
2.9	AX	AX	PT	—	all	$(A \neq B) \wedge (A // B)$
2.10	AX	AX	AX	—	all	$(A \neq B) \wedge (A // B) \wedge \neg (A // C)$
2.11	AL	AX	PL	—	all	$(A \neq B) \wedge (A // B) \wedge \neg (A // C)$
2.12	AX	PL	—	—	all	$\neg ((A // B) \vee (A \perp B))$
2.13	AX	PL	—	z	x, y, u, v, w	A // B (including $A \subset B$)
2.14	AX	PL	—	w	ρ_z, z, γ_z	$A \perp B$
2.15	AX	PL	PT	—	all	$(A // B)$
2.16	AX	PL	PT	—	all	$(A \perp B) \wedge (C \not\subset A)$
2.17	AX	PL	AX	—	all	$(A // B) \wedge \neg (A // C)$
2.18	AX	PL	AX	—	all	$(A \perp B) \wedge (A \neq C)$
2.19	AX	PL	PL	—	all	$(A // B) \wedge \neg (A // C)$
2.20	AX	PL	PL	—	all	$(A \perp B) \wedge \neg (A \perp C)$

Table 6: Plane as Primary Datum

Case	Datums A	Datums B	Datums C	Free xfrms	Invariants	Validity Conditions
3.1	PL	—	—	x, y, w	z, γ_z	—
3.2	PL	PT	—	w	z, γ_z, ρ_z	—
3.3	PL	PT	PT	—	all	$C \not\subset \{LI\ B : LI \perp A\}$
3.4	PL	PT	AX	—	all	$C \neq \{LI\ B : LI \perp A\}$
3.5	PL	PT	PL	—	all	$\neg (A // C)$
3.6	PL	AX	—	—	all	$\neg ((A // B) \vee (A \perp B))$
3.7	PL	AX	—	w	ρ_z, z, γ_z	$A \perp B$
3.8	PL	AX	—	x	y, z, u, v, w	A // B
3.9	PL	AX	PT	—	all	$(A \perp B) \wedge (C \not\subset B)$
3.10	PL	AX	PT	—	all	A // B
3.11	PL	AX	AX	—	all	$(A \perp B) \wedge (B \neq C)$
3.12	PL	AX	AX	—	all	$(A // B) \wedge \neg (B // C)$
3.13	PL	AX	PL	—	all	$(A \perp B) \wedge \neg (B \perp C)$
3.14	PL	AX	PL	—	all	$(A // B) \wedge \neg (B // C)$
3.15	PL	PL	—	x	y, z, u, v, w	$\neg (A // B)$
3.16	PL	PL	PT	—	all	$\neg (A // B)$
3.17	PL	PL	AX	—	all	$\neg (A // B) \wedge \neg (C // \{LI\ (A \cap B)\})$
3.18	PL	PL	PL	—	all	$\neg (A // B) \wedge \neg (C // \{LI\ (A \cap B)\})$