HexGen® Programming Guide

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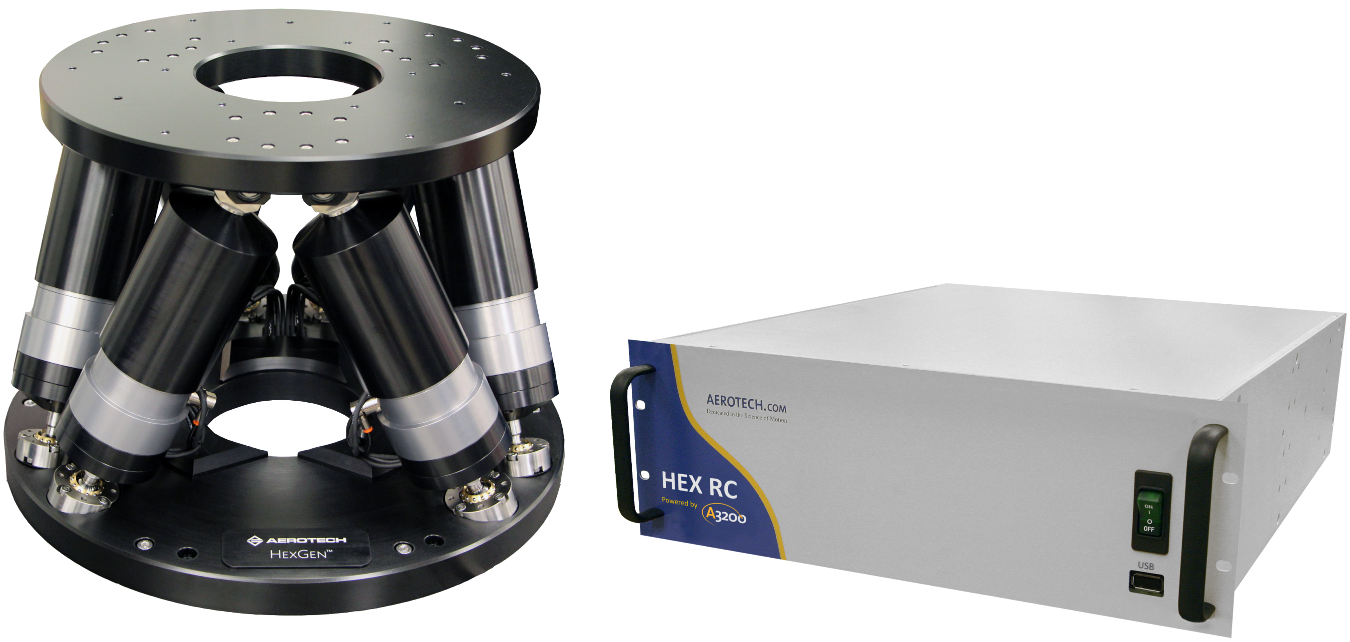

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Chapter 1: Programming Overview

NOTE: For warning and safety information and other important information about your Hexapod, refer to the hardware manual.

The application programming interface (API) for Hexapod programming is based on the A3200 motion control platform. Most programming features that you can use on the A3200 are also available on the Hexapod programming API.

But the programming features that follow apply only to the Hexapod Programming API.

- You must use commands that operate on virtual axes. For information about virtual axes, refer to the **Virtual Axes** topic in the A3200 Help file.
- To change the position of a virtual axis, you must use fixture offsets, motion commands, or preset position commands. For more information, refer to **Fixture Offsets Overview**, **Motion Command Category**, and **G92 Command (Set an Arbitrary Program Offset)** in the A3200 Help file.

1.1. Axis Definitions

When you do Hexapod programming, you write programs in a Cartesian frame that consists of three linear axes (X,Y,Z) and three rotary axes (A,B,C). The controller uses Bryant angles for rotations. It does them in the sequence of **A** rotation, then **B** rotation, and then **C** rotation. The values that the application shows for the axes can change based on the active programming mode and active tool that you use. For more information, refer to Chapter 7: Work Operating Mode and Chapter 8: Tool Operating Mode.

Chapter 2: Coordinate Systems

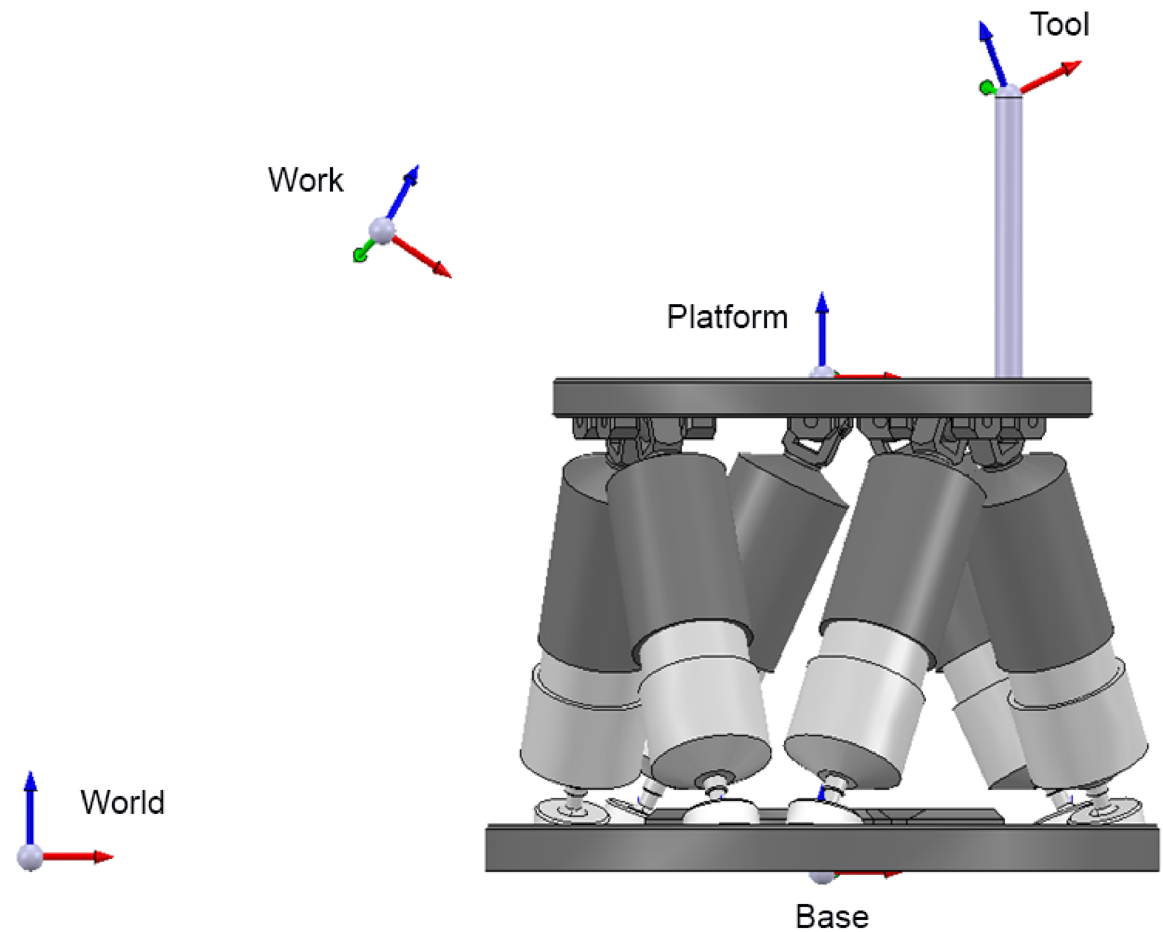

Figure 2-1: Coordinate Systems

2.1. World Coordinate System

The world coordinate system is a fixed frame. The *work* coordinate system and the Hexapod reference the world coordinate system.

If you do a strut-loading analysis, the Z axis must be parallel with the gravity vector of the Earth and positive Z must point in the opposite direction of the gravity acceleration vector.

If it is not necessary to do a strut-loading analysis, you can specify a Hexapod orientation that is applicable to your project.

2.2. Work Coordinate System

The work coordinate system is a fixed location in space about which the Hexapod can operate. For example, you can specify the location and orientation of the source of a collimated beam of light. You can also specify the location and orientation of a sensor or part fixture.

The location of the work coordinate system is defined relative to the location of the world coordinate system.

2.3. Base Coordinate System

The origin of the base coordinate system is at the center of the base mounting plate and has the same height as the bottom mounting surface. Refer to **Figure 2-1: Coordinate Systems**. The orientation of the base coordinate system can be different for each Hexapod. To find the orientation of the base coordinate system, refer to the drawing that Aerotech supplied for your Hexapod.

The location of the base coordinate system is defined relative to the location of the world coordinate system.

2.4. Platform Coordinate System

The origin of the platform coordinate system is at the center of the moving Hexapod platform and has the same height as the platform mounting surface. The positive Z axis is normal to the platform. The orientation of the platform coordinate system can be different for each Hexapod. To find the orientation of the platform coordinate system, refer to the drawing that Aerotech supplied for your Hexapod.

2.5. Tool Coordinate System

The tool coordinate system moves with the platform and specifies a point about which the Hexapod can translate and rotate. The current position of the Hexapod is the position of the tool in the work coordinate system. You can specify a maximum of three tool coordinate systems.

The location of the tool coordinate system is defined relative to the location of the platform coordinate system.

Chapter 3: Configuring Coordinate Systems

You can use macros to get access to the World to Work, World to Base, and Platform to Tool offsets. During program operation, you can change the offsets between coordinate systems as necessary. If you change the offsets while the work coordinate system is active, the controller calculates new values for the (X,Y,Z,A,B,C) axis positions. Motion does not occur as a result of changes that you make to the offsets.

You must set linear offsets along the axes of the anchor coordinate system to the target coordinate system. The anchor coordinate system is the coordinate system that does not move. The target coordinate system is the coordinate system that is located relative to the anchor coordinate system. You must set angular offsets as the angle required to align the anchor coordinate system with the target coordinate system. Rotations obey the right-hand rule for positive direction.

When you calculate angles, these calculations must obey the order of operations for Bryant angles.

where **A** rotates **B** and **C**.
and **B** rotates **C**.

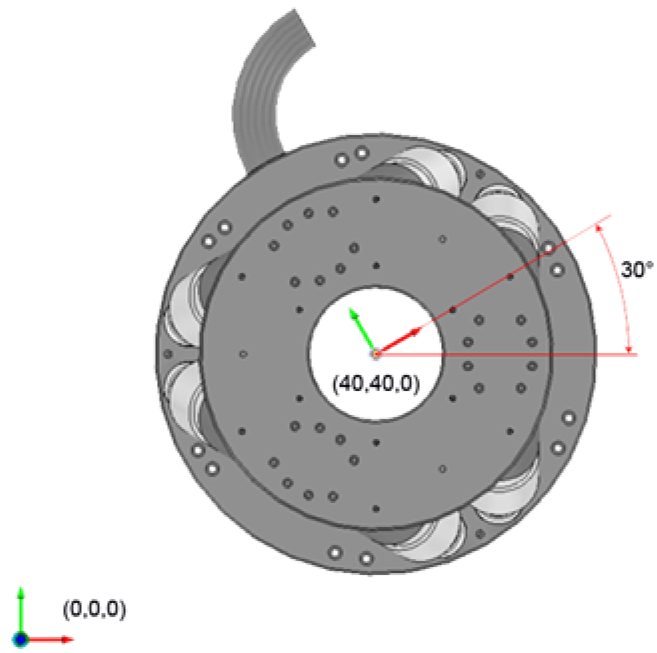

Figure 3-1: Base Offset Example

This figure shows the (X,Y,Z,A,B,C) axis positions at (40,40,0,0,0,30).

Chapter 4: World to Work Offsets

To set the world origin to work origin offsets, use the macro that follows.

SetWorldToWork(XOffset, YOffset, ZOffset, AOffset, BOffset, COffset)

where **XOffset**, **YOffset**, and **ZOffset** are the linear offsets.
and **AOffset**, **BOffset**, and **COffset** are the rotary offsets.

The default World to Work offset of (0,0,0,0,0,0) puts the world and work origins at the same location. You can issue the SetWorldToWork macro as necessary. When you issue this macro, the controller updates the (X,Y,Z,A,B,C) axis positions based on the new offsets.

Chapter 5: World to Base Offsets

To set the world origin to base origin offsets, use the macro that follows. The base origin is the base of the Hexapod.

SetWorldToBase(XOffset, YOffset, ZOffset, AOffset, BOffset, COffset)

where **XOffset**, **YOffset**, and **ZOffset** are the linear offsets.
and **AOffset**, **BOffset**, and **COffset** are the rotary offsets.

The default World to Base offset of (0,0,0,0,0,0) puts the center of the Hexapod base at the world origin. You can issue the SetWorldToBase macro as necessary. When you issue this macro, the controller updates the (X,Y,Z,A,B,C) axis positions based on the new offsets.

Chapter 6: Platform to Tool Offsets

To set the platform origin to tool origin offsets, use the macro that follows. The platform origin is the platform of the Hexapod. The default Platform to Tool offset of (0,0,0,0,0,0) puts the tool origin at the center of the Hexapod platform. You can specify a maximum of three tool coordinate systems.

You must issue the **SetToolPoint** macro before you issue the **ActivateTool** macro.

SetToolPoint(ToolIndex, “ToolName”, XOffset, YOffset, ZOffset, AOffset, BOffset, COffset)

where **ToolIndex** is the variable that you specify to tell the controller which of the three tools to use.
and **"ToolName"** is the name that you specify for each tool. The controller uses this variable to identify each tool in the program.
and **XOffset**, **YOffset**, and **ZOffset** are the linear offsets.
and **AOffset**, **BOffset**, and **COffset** are the rotary offsets.

To select a tool, use the macro that follows. When you issue this macro, the current (X,Y,Z,A,B,C) axis positions change based on the location of the tool that you select in the work coordinate system.

ActivateTool("ToolName")

where **"ToolName"** is the name that you specify for each tool. The controller uses this variable to identify each tool in the program.

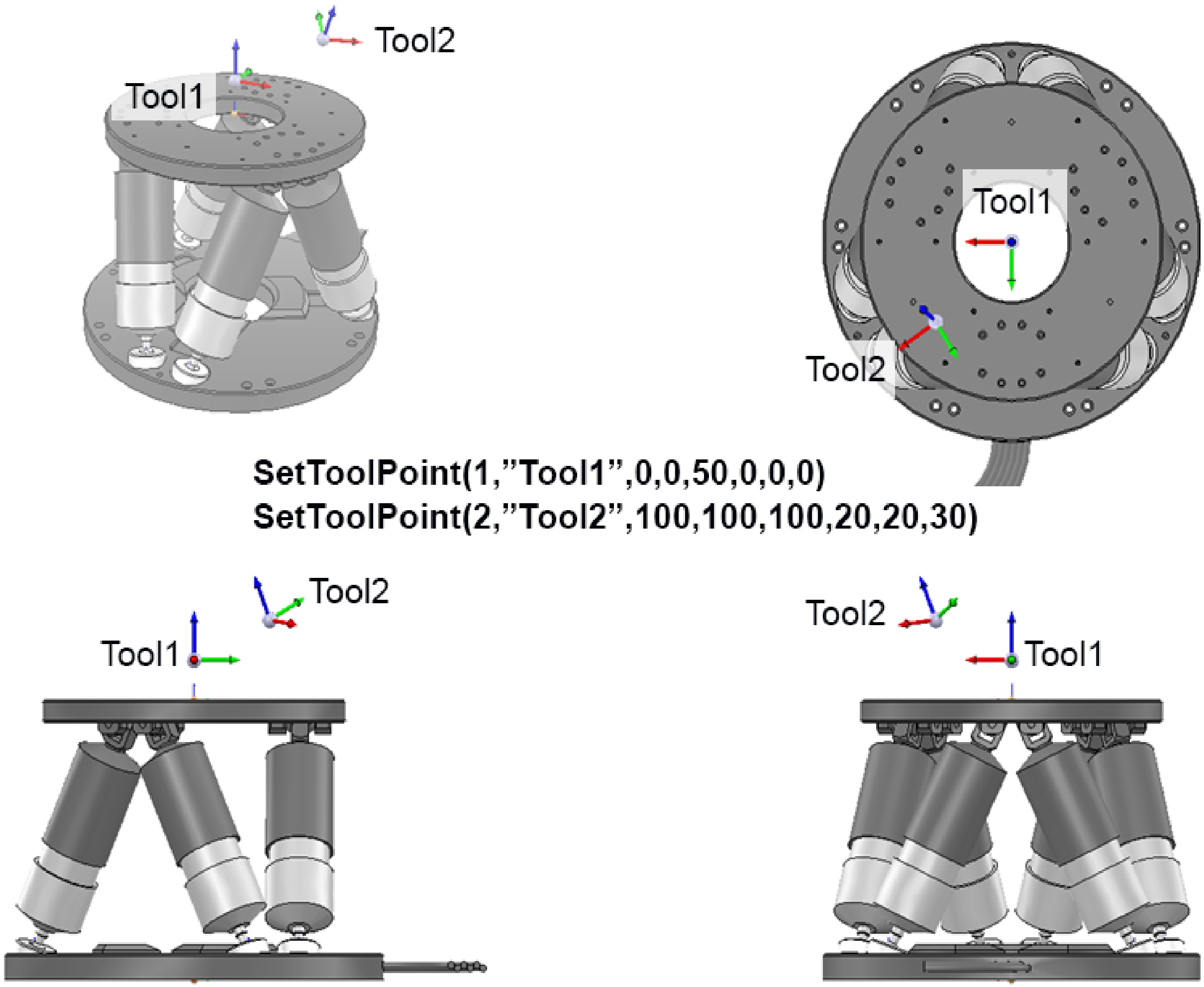

Figure 6-1: SetToolPoint Example

This figure shows two tools on a Hexapod system and their corresponding SetToolPoint macros.

Chapter 7: Work Operating Mode

The work and tool coordinate systems support motion commands. You can change between the work and tool operating modes as necessary. When you change the operating mode, the controller updates the (X,Y,Z,A,B,C) axis positions based on the orientation of the Hexapod in the new operating mode. To see a list of motion commands that you can use, refer to **Motion Command Category** in the A3200 Help file.

In work operating mode, the displayed position of the Hexapod is the location of the active tool in the work coordinate system. If you change the active tool, the controller updates the position of the Hexapod based on the location and orientation of the new tool. Motion does not occur as a result of you changing the active tool.

Linear (X,Y,Z) motion is always aligned to the work coordinate system. Rotations occur about the tool center. Refer to Chapter 10: Motion in Work and Tool Operating Modes for more information.

WARNING: Make sure there are no collision conditions that can occur. You must do this before you enable a Hexapod that has incremental encoder feedback.

To enable Work operating mode and the Hexapod, issue the macro that follows.

```
EnableWork
```

Your Hexapod contains either absolute feedback devices or incremental feedback sensors. When you enable the Hexapod, it operates based on its feedback type.

7.1. Hexapod That Has Absolute Feedback Devices

This type of Hexapod does not move. The controller uses the absolute position of each strut to calculate the current position and orientation of the Hexapod.

7.2. Hexapod That Has Incremental Feedback Sensors

This type of Hexapod starts to move and does a reference cycle only if it did not previously complete one. If this Hexapod previously completed a reference cycle, it moves to the mid-travel position.

Chapter 8: Tool Operating Mode

The work and tool coordinate systems support motion commands. You can change between the work and tool operating modes as necessary. When you change the operating mode, the controller updates the (X,Y,Z,A,B,C) axis positions based on the orientation of the Hexapod in the new operating mode. To see a list of motion commands that you can use, refer to **Motion Command Category** in the A3200 Help file.

When you first enable tool operating mode or you enable a new tool, the controller sets the (X,Y,Z,A,B,C) axis positions to 0. Linear (X,Y,Z) motion is always aligned with the tool coordinate system. If you include commands in your program that tell the controller to rotate the tool coordinate system, this rotation changes the direction of subsequent linear motion.

WARNING: Make sure there are no collision conditions that can occur. You must do this before you enable a Hexapod that has incremental encoder feedback.

To enable tool operating mode and the Hexapod, issue the macro that follows.

```
EnableTool
```

Your Hexapod contains either absolute feedback devices or incremental feedback sensors. When you enable the Hexapod, it operates based on its feedback type.

8.1. Hexapod That Has Absolute Feedback Devices

This type of Hexapod does not move. The controller uses the absolute position of each strut to calculate the current position and orientation of the Hexapod.

8.2. Hexapod That Has Incremental Feedback Sensors

This type of Hexapod starts to move and does a reference cycle only if it did not previously complete one. If this Hexapod previously completed a reference cycle, it moves to the mid-travel position.

Chapter 9: Disabling Hexapod Transformations

To disable the real-time Hexapod kinematics, issue the macro that follows.

```
DisableHexapod
```

After you issue the DisableHexapod macro, you get full control of each strut. Strut axes are named ST1 through ST6. Until you reset or power cycle the controller, it stores all the information from previous tool and offset settings.

Chapter 10: Motion in Work and Tool Operating Modes

The images that follow show the differences in motion between the work and tool operating modes. These conditions apply.

- The World to Work and World to Base offsets are set to 0.
- The world and work origins are at the same location as the base origin of the Hexapod.
- When you issue the SetToolPoint macro that follows, the controller updates the location of the tool to 100 mm above the Hexapod platform. Then it rotates the tool 45° about the Z axis.

```
SetToolPoint(1, "Tool1", 0, 0, 100, 0, 0, 45)
```

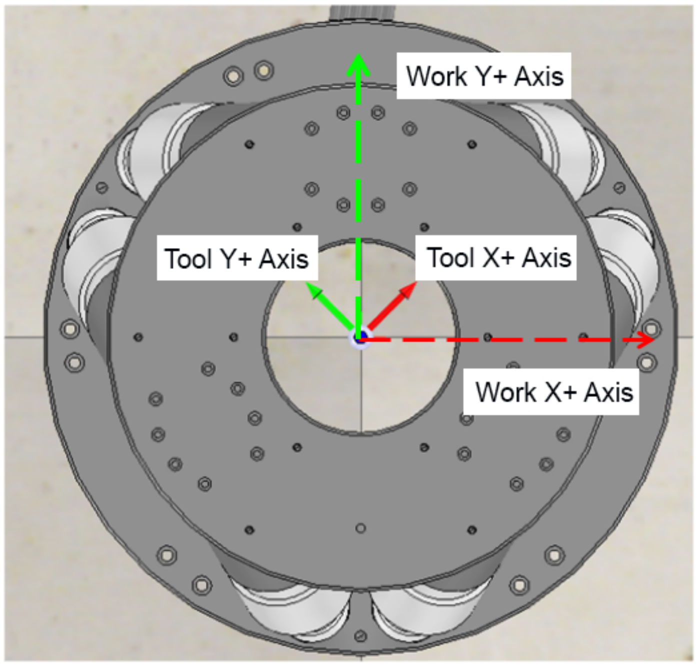

Figure 10-1: Hexapod at (0,0,0,0,0,0) Position

In the work operating mode, positive motion on the X axis occurs left to right and positive motion on the Y axis occurs up and down.

The images that follow show the differences in motion between the work and tool operating modes.

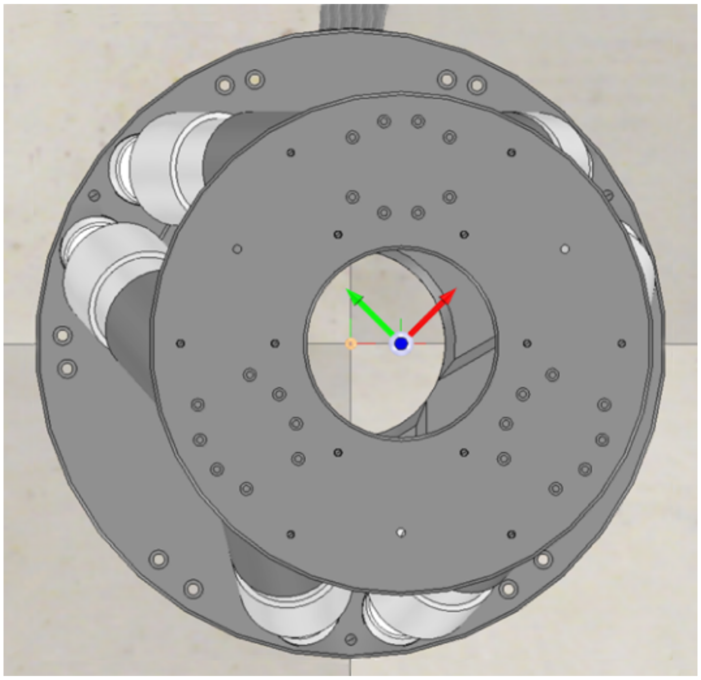

Figure 10-2: Hexapod at (40,0,0,0,0,0) Position

In work operating mode, an X axis command of 40 mm causes motion along the X axis in the work coordinate system.

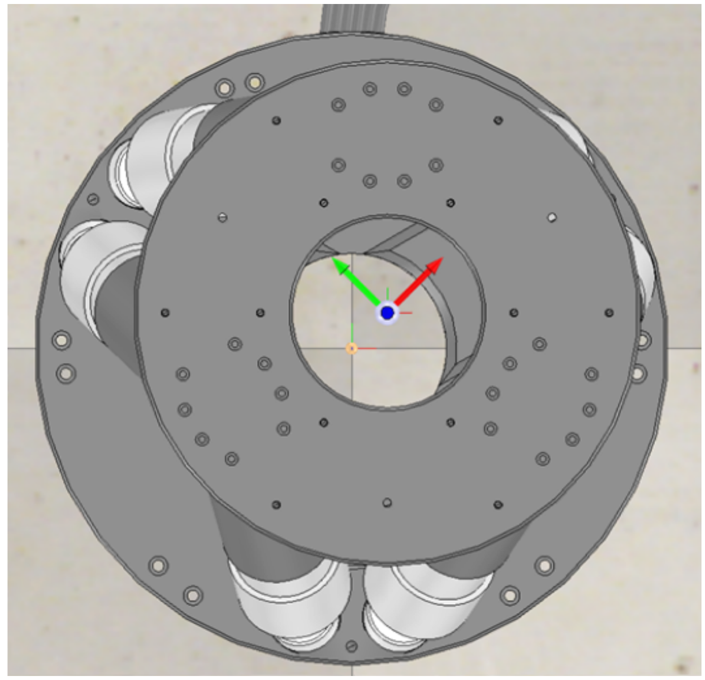

Figure 10-3: Hexapod at (40,0,0,0,0,0) Position

In tool operating mode, an X axis command of 40 mm causes motion along the X axis in the tool coordinate system.

The images that follow show the differences in motion between the work and tool operating modes.

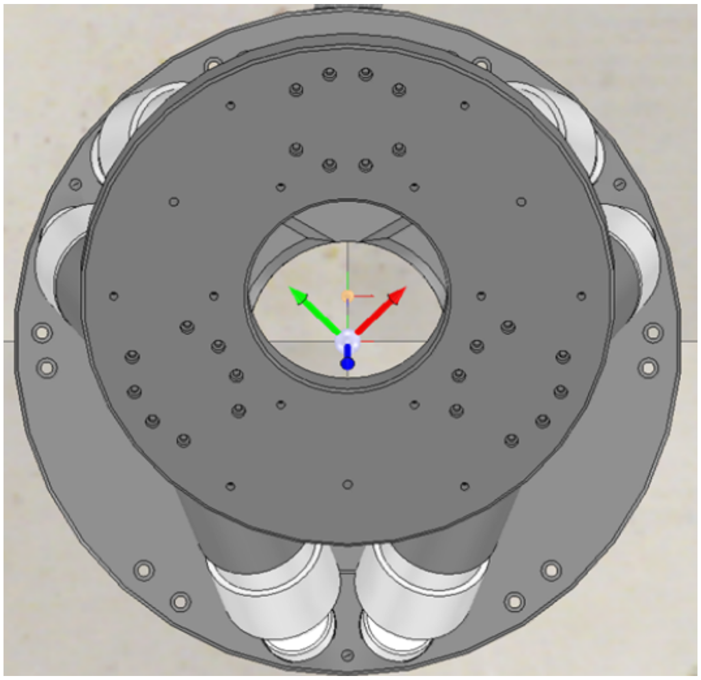

Figure 10-4: Hexapod at (0,0,0,20,0,0) Position

In work operating mode, the controller rotates the A axis 20° about an axis that is parallel to the X axis of the work coordinate system. This rotation occurs through the active tool origin.

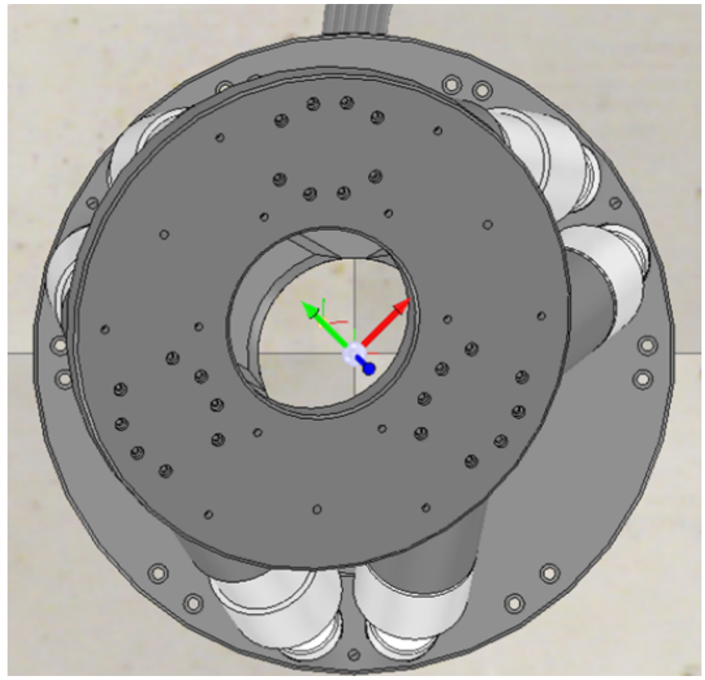

Figure 10-5: Hexapod at (0,0,0,20,0,0) Position

In tool operating mode, the controller rotates the A axis 20° about the X axis in the tool coordinate system.

Chapter 11: Hexapod Example

This example program uses a HEX500-350HL Hexapod. The height of the Hexapod platform is 350 mm when the struts are at the mid-travel position. When you run this program, it enables the Hexapod in work operating mode and executes the sequence of operations that follow.

NOTE: Aerotech recommends that you give initial values to all tools and offsets at the start of the program. This lets the controller overwrite settings from a previous operation and use the correct configuration for the current process.

EXAMPLE

```
' Disable the Hexapod to make sure it was not previously enabled.
DisableHexapod
' Set the offsets.
SetWorldToBase(0,0,0,0,0,0)
SetWorldToWork(0,0,0,0,0,0)
' Enable and initialize the Hexapod.
SetToolPoint(1, "Tool1", 0, 0, 100, 0, 0, 45)
ActivateTool("Tool1")
EnableWork
' Enable absolute positioning.
ABSOLUTE
' Set the speed to 10 mm/s.
F10
' Do a linear move.
LINEAR X10 Y5 Z470
' Change to tool operating mode.
EnableTool
' Move the B axis -10°, which is a rotation about the Tool Y.
LINEAR B-10
' Change back to work operating mode.
EnableWork
' Change the WorldtoWork offset.
SetWorldToWork(100,100,300,0,0,0)
' Send the rotary axes back to their 0 angles.
RAPID A0 B0 C0
```

After the program changes from work operating mode to tool operating mode and back to work operating mode, the controller updates the (X,Y,Z,A,B,C) axis positions based on the active mode and the location of the tool.

For information about the updated axis positions for completed commands, refer to the table that follows.

Table 11-1: Updated (X,Y,Z,A,B,C) Axis Positions

Syntax	Axis Positions	Explanation
EnableWork	(0,0,450,0,0,0)	The initial height of the Z axis is 450 because Tool1 has a Z offset of 100 and the Hexapod has a nominal height of 350 for the Z axis.
LINEAR X10 Y5 Z470	(10,5,470,0,0,0)	In work operating mode with absolute positioning active, the displayed positions of the (X,Y,Z,A,B,C) axes is the location of the tool in the work coordinate system.
EnableTool	(0,0,0,0,0,0)	When the controller enters tool operating mode, it sets the angles and (X,Y,Z,A,B,C) axis positions to 0.
LINEAR B-10	(0,0,0,0,-10,0)	The Hexapod rotates -10° about the Tool B axis.
EnableWork	(10,5,470,7.197,-7.05,0.4387)	Because the controller did not execute motion commands on the (X,Y,Z) axes, the (X,Y,Z) axis positions are the same as they were before the controller enabled the tool coordinate system. The Hexapod changes the angles because the controller rotated the "Tool1" coordinate system 45°. As a result, the -10° B axis move in the tool coordinate system is a compound move for the (A,B,C) axes in the work coordinate system.
SetWorldToWork (100,200,300,0,0,0)	(-90,-195,170,7.107,-7.05,0.438)	The work origin was initially aligned with the base origin of the Hexapod. The SetWorldtoWork macro shifts the work origin 100 mm in the X axis, 200 mm in the Y axis, and 300 mm in the Z axis. With no angular offsets active, the Hexapod subtracts linear offsets from the previous tool position in the world coordinate system to calculate the new tool position. When the Hexapod subtracts (100,200,300), the current positions of the (X,Y,Z) axes change to (-90,-195,170).

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