The MotionMonitor xGen Software Guide: Metal Mapping and Distortion Correction

This document reviews the configuration of mapping functions to correct readings from magnetic trackers (Ascension & Polhemus systems) that may have been distorted by environmental conditions. Typically, standard range transmitters do not require mapping as they can often be moved away from sources of distortion.

Prior to performing any type of metal mapping, testing should be performed to determine if environmental distortion exists and the extent that the data capture volume would need to be mapped. To confirm or test for environmental distortion, two sensors can be affixed to a rigid, nonferrous, rod and then moved through the measurement space. It is recommended to have the sensors directed in the same general orientation as each other, as this will make the relative orientation data easier to evaluate. Since the sensors on the rod are stationary to each other, the reported values will remain stable in the absence of distortion or noise. As the rod is moved through the space, the user can determine the amount of variation from one part of the space to another. If the variation is excessive, it may indicate the need for a metal mapping to recalibrate the space. Please note that the noise is expected to increase as the sensors move farther from the transmitter and that this would not be reason for performing a mapping.

The Analysis Variables displayed in the image below demonstrate how the position and orientation of one sensor can be easily examined relative to another sensor.

Analysis variables	x
Type: Scalar v Name: PositionX Expression: Use drop-lists v Ascension1 v Sensor1 v Axes v Pos v X v no derivative v relative	to Ascension1 V Sensor2 V Axes V
Type: Scalar V Name: PositionY Expression: Use drop-lists V Ascension1 V Sensor1 V Axes V Pos V V V no derivative V relative	to Ascension1 V Sensor2 V Axes V
Type: Scalar V Name: PositionZ Expression: Use drop-lists V Ascension1 V Sensor1 V Axes V Pos V Z V no derivative V relative	to Ascension1 V Sensor2 V Axes V
Type: Scalar Name: OrientationZ Expression: Use drop-lists Ascension1 Sensor1 Axes Ori Eul ZYX Z Ino derivation	tive v relative to Ascension1 v Sensor2 v Axes v
Type: Scalar Name: OrientationY Expression: Use drop-lists Ascension1 Sensor1 Axes Ori Eul ZYX Y no derivation	tive v relative to Ascension1 v Sensor2 v Axes v
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Calar Variable	

Use the following links to jump to their respective sections in the document.

Performing a metal map using the "Grid" method

Loading an existing metal map file

Distortion correction with hybrid hardware configuration

Performing a metal map using the "Grid" method

1. Start The MotionMonitor xGen and go to the Hardware node in the Setup Components window. From the Ascension or Polhemus node, click on the "Correct Distortion" button.

Components	x
🖌 Setup 🗧 Analysis	
, World Axes	^
Camera1	
∕ Stylus1	
> 🙏 Ascension1	~
Ascension name: Ascension1	
Measurement rate: 238.0952381	
Synchronizing event: when Use drop-lists	
▼ Setup	
Transmitter type: ERT, 144" V	
Report rate: 3	
Confirm settings	
Stylus to use: 🖊 Stylus 1 🗸 NOTE: Stylus rigid body must be an Ascension sensor	
Distortion correction in use: None	
Distortion correction boundary width: 0	m
Correct Distortion	
▼ Advanced	
Suspend live data (reduces CPU requirements by making data only available in post-processing)	
Sctivate	

The software will specify whether a metal mapping is currently applied as well as the name of the metal mapping file in use following the "Distortion correction in use" text, as seen in the image above. The "Distortion correction boundary width" setting is not used by the distortion correction metal mapping algorithm. This parameter is only used for mappings created with the "Align to Other Hardware" alignment, which uses a polynomial fitting algorithm and will be reviewed at the end of this document.

2. Select "No" when asked to remove all existing distortion correction and just use native hardware readings. Selecting "Yes" will clear the current mapping and result in the software going back to using uncorrected sensor position and orientation data. Selecting "Cancel" will exit the process.

🏟 The MotionMonitor		_		×
Do you want to remove all existing distortion	correction and ju	st use native hard	lware rea	dings?
	Yes	No	Cano	el

3. Select "No" when prompted to use a previously captured mapping file.



4. Specify the distortion correction parameters for the metal map. Select the sensor to use for capturing readings during the process and the Is-button-pressed expression if using a handheld event marker as a remote OK button to advance through the software dialogs. The number of X, Y and Z divisions represent the number of points or layers to take in the mapping. All readings and axis directions are in the transmitter's default, native, coordinate system. The Grid spacing indicates the spacing between each point.

Distortion Correction Parameters	_		×
Ascension sensor to use: Sensor 1 $ \smallsetminus $			
Is-button-pressed expression: Use drop-lists $\ ee$ Stylus1	~	Button 🗸	
Grid spacing: 0.1			m
Number of X divisions: 7			
Number of Y divisions: 7			
Number of Z divisions: 12			
\square Specify actual first position of sensor: Use drop-lists \lor <	ino sele	ection> 🖂	
\Box Specify actual orientation of sensor: Use drop-lists \checkmark <n< td=""><td>o selec</td><td>tion> 🗸</td><td></td></n<>	o selec	tion> 🗸	
Resampled grid spacing: 0.05			m
	Ж	Cance	ł

Generally, it is assumed that the closest readings to the transmitter are in undistorted space. However, certain environments may contain a large distortion throughout the volume, even when closer to the transmitter. The "Specify actual first position of sensor" and "Specify actual orientation of sensor" are meant to provide a means to perform a metal mapping when there is significant distortion throughout the capture volume.

The orientation of the sensor is meant to remain fixed across all the mapping readings, the "Specify actual orientation of sensor" is the orientation of the sensor relative to the transmitter during the mapping process. The orientation of the sensor can be reported as rot(Yaw, Pitch, Roll), where Yaw (Z), Pitch (Y) and Roll (X) are angles relative to the transmitter's default, native, coordinate system. The "Specify actual first position of sensor" would be the actual position of the first mapping position (reading (0,0,0)). The position can be specified as vec(X, Y, Z), where x, y and z are the X, Y and Z positions reported in meters relative to the transmitter's default, native, coordinate system. While this might involve some error from the actual measurement of where the first position of the metal mapping grid is (using a ruler or tape measure), it would only be necessary in cases where there is significant distortion, even close to the transmitter. Also, the mapping algorithm is more susceptible to errors in orientation than position, so the orientation field would be more important to specify, and to get correct, than the position. An inaccurate position may only result in an initial shift of where the "origin" of the world is. All positions would be reported relative to that same world axes origin location.

The "Resampled grid spacing" edit field effectively adds additional data points in the mapping correction to the points that are actually digitized. This parameter will be better at reducing absolute errors when it has a smaller value, and better at reducing relative errors when it has

a larger value. As a general rule, the best results with this parameter is typically one that is less than the original grid spacing, but it does not need to be significantly less.

Save File				×
$\leftrightarrow \rightarrow \cdot \uparrow$	« Ascension > Metalma	ps v Ö	Search Metalmaps	Q
Organize 🔻 🛛 N	ew folder			
Name	^	Date modified	Туре	Size
File <u>n</u> ame	MetalMap			~
Save as <u>t</u> ype	Metal Map Files (*.txt)			~
 Hide Folders 			<u>S</u> ave	Cancel

Click "OK" and select a name for the metal map file and to begin the process of capturing points for the metal mapping.

5. The software will then proceed through capturing the points for the metal map as defined in the Distortion Correction Parameters dialog. The readings are taken in order, first on x, then y, then z axes, consistent with that of the transmitter' default, native, coordinate system.

	🏽 The MotionMonitor 🚽 🗆 🗙
	Place Sensor 1 at position (0, 0, 0). OK Back Cancel
space C	apturing Distortion Correction Point ? X
Captu	ring distortion-correction point Cancel

The positioning of the grid should be aligned as best possible with the transmitter's axes system, as seen in the following sample images.

The following images provide a visual representation for how the "grid" method can be performed. This example uses a modified anthropometer, bubble level and grid, as shown here.



The sensor designated in Distortion Correction Parameters dialog is firmly attached to the milled "slider" shelf on the anthropometer. The sensor orientation does not matter but will need to remain constant throughout the entirety of the mapping process. The grid is then laid out in the measurement space that is to be mapped, using the grid spacing previously specified in the dialog.



The user should take note of the initial position of the slider. As readings are taken in the upper layers of the grid, it will be necessary to move the slider by the grid spacing previously specified in the dialog.



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As the anthropometer is moved to successive points in the grid, care must be taken to ensure that the anthropometer is placed in the same relative position and orientation.

The cross member in the base of the anthropometer should be carefully aligned with the grid; the point on the grid should be accurately positioned at a common point on the anthropometer base. In addition, the bubble level should be observed to ensure that the anthropometer is perfectly vertical.



<image>

When the layer of x, y points has been recorded, the "slider" should be moved by the spacing specified in the dialog box....

When all the points have been recorded, the Parameter panel for the hardware device now indicates the name of the distortion correction file is in use.

Components		2
🖌 Setup 🛛 🔤 Analysis		
→ World Axes → ⇔ Hardware ○ Camera1 → Stylus1 → ▲ Ascension1		Î
A rescionit		v
Ascension name: Ascension1		
Measurement rate: 238.0952381		
Synchronizing event: when	Jse drop-lists V <no selection=""> V becomes true</no>	i.
▼ Setup		
Transmitter brook EDT 144" v	The MotionMonitor — 🗆 🗙	
Parasterter 2	Ascension 1 was successfully corrected for distortion.	
	ОК	
Stylue to user / Stylue 1	NOTE: Stylus rigid body must be an Ascension sensor	
Distortion correction in use: Meta	allan tyt	
Distortion correction houndary wi	dth: 0	m
		· · · · ·
Correct Distortion	how Distortion	
Advanced		
Suspend live data (reduces Cl	PU requirements by making data only available in post-processing)	
	Align to Others Used was	

6. Click on the "Show Distortion" button for a visual representation of your metal mapping correction in an interactive 3D Animation window. An example of a metal mapping distortion correction is displayed below. The Green dots represent the actual positions for the grid. The Red dots represent the raw positions that were captured. The Blue dots represent the corrected readings for the sensor data.



Loading an existing metal map file

1. Start The MotionMonitor xGen and go to the Hardware node in the Setup Components window. From the Ascension or Polhemus node, click on the "Correct Distortion" button.

Components	×
🗲 Setup 🔤 Analysis	
, World Axes ✓ ✿ Hardware O Camera 1	^
Stylus1 Ascension1	,
Ascension name: Ascension1	
Measurement rate: 238.0952381	
Synchronizing event: when Use drop-lists \checkmark <no selection=""> \checkmark becomes true</no>	
▼ Setup	_
Transmitter type: ERT, 144" ∨	
Report rate: 3	
Confirm settings	
Stylus to use: 📝 Stylus1 🗸 NOTE: Stylus rigid body must be an Ascension sensor	
Distortion correction in use: None	
Distortion correction boundary width: 0 n	n
Correct Distortion	
▼ Advanced	_
Suspend live data (reduces CPU requirements by making data only available in post-processing)	
Activate	

The software will specify whether a metal mapping is currently applied as well as the name of the metal mapping file in use following the "Distortion correction in use" text, as seen in the image above. The "Distortion correction boundary width" setting is not used by the distortion correction metal mapping algorithm. This parameter is only used for mappings created with the "Align to Other Hardware" alignment, which uses a polynomial fitting algorithm and will be reviewed at the end of this document.

2. Select "No" when asked to remove all existing distortion correction and just use native hardware readings. Selecting "Yes" will clear the current mapping and result in the software going back to using uncorrected sensor position and orientation data. Selecting "Cancel" will exit the process.

🕸 The MotionMonitor		_		×
Do you want to remove all existing distortion o	orrection and ju	ust use native hard	ware rea	adings?

3. Select "Yes" when prompted to use a previously captured mapping file.



The Distortion Correction Parameters dialog provides the option for enabling the "Specify actual orientation of sensor" and "Specify actual first position of sensor" and to set the "Resampled grid spacing".

Distortion Correction Parameters	- 🗆 X
Specify actual first position of sensor:	Use drop-lists $\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$
Specify actual orientation of sensor:	Use drop-lists $ {}^{<}$ <no selection=""> ${}^{<}$</no>
Resampled grid spacing: 0.05	m
	OK Cancel

As described previously, it is assumed that the closest readings to the transmitter are in undistorted space. However, certain environments may contain a large distortion throughout the volume, even when closer to the transmitter. The "Specify actual first position of sensor" and "Specify actual orientation of sensor" are meant to provide a means to perform a metal mapping when there is significant distortion throughout the volume. The orientation of the sensor is meant to remain fixed across all the mapping readings, the "Specify actual orientation of sensor" is the orientation of the sensor relative to the transmitter during the mapping process. The orientation of the sensor can be reported as rot(Yaw, Pitch, Roll), where Yaw (Z), Pitch (Y) and Roll (X) are angles relative to the transmitter's default, native, coordinate system The "Specify actual first position of sensor" would be the actual position of the first mapping position (reading (0,0,0)). The position can be specified as vec(X, Y, Z), where x, y and z are the X, Y and Z Scalar positions reported in meters relative to the transmitter's default, native, coordinate system. While this might involve some error from the actual measurement of where the first position of the metal mapping grid is (using a ruler or tape measure), it would only be necessary in cases where there is significant distortion, even close to the transmitter. The mapping algorithm is more susceptible to errors in orientation than position, so the orientation field would be more important to specify than the position. An inaccurate position may only result in an initial shift of where the "origin" of the world is. All positions would be reported relative to that same world axes location.

The "Resampled grid spacing" edit field effectively adds additional data points in the mapping correction to the points that are actually digitized. This parameter will be better at reducing absolute errors when it has a smaller value, and better at reducing relative errors when it has a larger value. As a general rule, the best results with this parameter is typically one that is less than the original grid spacing, but it does not need to be significantly less.

Select a name for the metal map file. Each metal map is unique to the transmitter position/orientation and environmental sources of distortion. Note: Mapping files generated using The MotionMonitor Classic can also be selected here.

🕸 Open File							×
$\leftarrow \rightarrow \land \uparrow$	K User > Ascension	n > Metalmaps	ٽ ~	Search Metaln	naps		9
Organize 🔻	New folder						?
Name	^	Date modified	Туре	Size			
		No items match you	r search.				
	File <u>n</u> ame:		~	Metal Map Fi	es (*.txt)		\sim
				<u>O</u> pen	0	ancel	

The Parameter panel for the hardware device now indicates which distortion correction file is in use.

 Setup Analysis World Axes Hardware Camera1 Stylus1 Ascension 1 Ascension name: Ascension1 Stup Transmitter type: ERT, 144* Report rate: 3 Stylus to use: Stylus 1 NOTE: Stylus rigid body must be an Ascension sensor Distortion correction in use: MetalMap.txt Distortion correction boundary width: 0 m <pm< p=""> m m <pm< p=""> m m <pm< p=""> m<!--</th--><th>Components</th><th></th><th>x</th></pm<></pm<></pm<>	Components		x
World Axes World Axes Hardware Camera1 Stylus1 Ascension name: Ascension1 Ascension name: Ascension1 Ascension name: Ascension1 Ascension name: Z38.0952381 Synchronizing event: when Use drop-lists Conselection> becomes true Setup Transmitter type: ERT, 144* Report rate: 3 Conselection1 was successfully corrected for distortion. Kacension 1 was successfully corrected for distortion. Kacension 1 was successfully corrected for distortion. Conselection correction in use: MetalMap.txt Distortion correction boundary width: 0 Conselection MetalMap.txt Distortion correction boundary width: 0 Conselection MetalMap.txt Distortion correction boundary width: 0 Conselection MetalMap.txt MetalM	🖌 Setup 🔤 Analysis		
Ascension name: Ascension1 Measurement rate: 238.0952381 Synchronizing event: when Use drop-lists < <no selection=""> becomes true Setup Transmitter type: ERT, 144* Report rate: 3 Confirm settings Stylus to use: Stylus 1 NOTE: Stylus rigid body must be an Ascension sensor Distortion correction in use: MetalMap.txt Distortion correction boundary width: 0 mm Correct Distortion Stylus Distortion</no>	 ↓ World Axes ↓ Hardware Camera1 ↓ Stylus1 ↓ Ascension1 		~
Measurement rate: 238.0952381 Synchronizing event: when Use drop-lists < <no selection=""> Setup Transmitter type: ERT, 144* Report rate: 3 Confirm settings Stylus to use: Stylus 1 NOTE: Stylus rigid body must be an Ascension sensor Distortion correction in use: MetalMap.txt Distortion correction boundary width: 0 m</no>	Ascension name: Ascension1		
Synchronizing event: when Use drop-lists < no selection > becomes true ✓ Setup The MotionMonitor — × Transmitter type: ERT, 144* Ascension 1 was successfully corrected for distortion. ✓ Confirm settings OK OK Stylus to use: ✓ Stylus 1 NOTE: Stylus rigid body must be an Ascension sensor Distortion correction in use: MetalMap.txt MetalMap.txt m Distortion ﷺ Show Distortion >	Measurement rate: 238.0952381		
Setup Image: The MotionMonitor Image: Confirm settings Image: Correct Distortion Image: Correct Distortion Image: Correct Distortion	Synchronizing event: when Use	e drop-lists 🔗 <no selection=""> 🔗 becomes true</no>	
Transmitter type: ERT, 144" Report rate: 3 Confirm settings OK Stylus to use: Stylus 1 v NOTE: Stylus rigid body must be an Ascension sensor Distortion correction in use: MetalMap.txt Distortion correction boundary width: 0 m Show Distortion	▼ Setup		
Report rate: 3 Confirm settings OK Stylus to use: Stylus ' NOTE: Stylus to use: Stylus rigid body must be an Ascension sensor Distortion correction in use: MetalMap.bxt Distortion correction boundary width: 0 Image: Correct Distortion Image: Show Distortion	Transmitter type: FRT_144" V	🗱 The MotionMonitor — 🗆 🗙	
Confirm settings OK Stylus to use: Stylus I v NOTE: Stylus rigid body must be an Ascension sensor Distortion correction in use: MetalMap.txt Distortion correction boundary width: 0 m Show Distortion	Report rate: 3	Ascension 1 was successfully corrected for distortion.	
Stylus to use: Stylus 1 NOTE: Stylus rigid body must be an Ascension sensor Distortion correction in use: MetalMap.txt Distortion correction boundary width: 0 m Steret Distortion Show Distortion	Confirm settings	ОК	,
Distortion correction in use: MetalMap.txt Distortion correction boundary width: 0 m	Chalus have Chalus 1		
Distortion Correction boundary width: 0 m Correct Distortion	Distastian secondian in una MatalM	TE: Stylus rigid body must be an Ascension sensor	
Correct Distortion	Distortion correction boundary width		m
A Correct Distortion			
	Snov	V Distortion	
▼ Advanced	▼ Advanced		
Suspend live data (reduces CPU requirements by making data only available in post-processing)	Suspend live data (reduces CPU	requirements by making data only available in post-processing)	
Activate Align	🥩 Activate 🛛 🧮 Align	Align to Other Hardware	

3. Click on the "Show Distortion" button for a visual representation of your metal mapping correction in an interactive 3D Animation window. An example of a metal mapping distortion correction is displayed below. The Green dots represent the actual positions for the grid. The Red dots represent the raw positions that were captured. The Blue dots represent the corrected readings for the sensor data.



Distortion correction with hybrid hardware configuration

If capturing passive or active optical camera data with an electromagnetic system (Ascension or Polhemus) a dynamic distortion correction can be performed by taking simultaneous readings from a sensor or rigid body from each hardware device when the sensors are affixed to a rigid, non-ferrous, object and then moved through the measurement space.

1. Start The MotionMonitor xGen and go to the Hardware node in the Setup Components window. From the Ascension or Polhemus node, click on the "Align to Other Hardware" button.

Components	×
🖌 Setup 📉 Analysis	
, World Axes	^
Y 🔅 Hardware	
Camera1	
Stylus1	
> 🙏 Ascension1	~
Ascension name: Ascension 1	
Measurement rate: 238.0952381	
Synchronizing event: when Use drop-lists </ul	
▼ Setup	
Transmitter type: ERT, 144" V	
Report rate: 3	
Confirm settings	
Stylus to use: // Stylus1 / NOTE: Stylus rigid body must be an Ascension sensor	
Distortion correction in use: None	
Distortion correction boundary width: 0	m
Correct Distortion	
▼ Advanced	
Suspend live data (reduces CPU requirements by making data only available in post-processing)	
Activate	

The "Distortion correction boundary width" setting is a polynomial fitting algorithm that determines the thickness of the region surrounding the mapped area where the degree of distortion correction will taper off to zero when "Align to Other Hardware" alignment is used.

2. Specify the parameters in the Hardware Alignment Parameters. For the distortion correction to be performed, enable the "Calculate third-order distortion correction" otherwise the hardware devices coordinate systems will only be aligned. Specify the electromagnetic sensor to use along with the other hardware's sensor or 6DoF rigid body to be used and the Is-button-pressed expression if using a handheld event marker as a remote OK button to advance through the software dialogs. The Measurement interval and Number of readings edit fields will determine how often the readings are captured and the number of readings to include in the distortion correction, respectively. Click "OK" to proceed.

🗱 Hardware Alignment Parameters	—	
Calculate third-order distortion correction		
Ascension sensor to use: Sensor 1 $$		
Other hardware's rigid body: Use drop-lists $\ \lor$ <no selection=""></no>	\sim	
Is-button-pressed expression: Use drop-lists $$		\sim Button \sim
Measurement interval: 100		msec
Number of readings: 300		
	ОК	Cancel

3. After ensuring that the sensors from both hardware systems are attached to the same rigid object, click "OK" to proceed with the capturing of the distortion correction points.

88 The MotionMonitor	_		×
Attach the Ascension sensor and the other hardware system's rigid body to a wand, minimizing the distance between them. After hitting OK, move the wand slowly through the measurement space	e for the n DK	ext 30 s Can	econds.

Capturing Colocation Readings	?	×
Move the wand slowly through the measurement space until the next me	ssage a	ppears. Icel

4. After capturing the distortion correction readings, the software will report the pre and post position RMS errors followed by the pre and post and orientation RMS errors.

🌆 The MotionMonitor	2 <u>068</u> 5		×
Ascension 1 uncorrected colocation po	sition RMS erro	or: 1.036	501 cm
Do you accept this alignment?	No	Cano	el
🗱 The MotionMonitor	_		×
Ascension 1 corrected colocation posi	tion RMS error	: 0.652	227 cm
Do you accept this alignment? Yes	No	Cano	:el
🕸 The MotionMonitor	_		×
Ascension 1 uncorrected colocation orient	ation RMS erro	or: 5.202	8 degrees
Do you accept this alignment?			
Yes	No	C	ancel
🕸 The MotionMonitor	_		×
Ascension1 corrected colocation orientat	ion RMS error	: 4.8232	6 degrees
Do you accept this alignment? Yes	No	0	ancel

5. If accepted, this distortion correction will be applied to the electromagnetic hardware data.

