

# **Coda cx1 Long Form Functional Test Procedure**

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# **1. Introduction**

## **1.1 Activity Description**

This procedure provides a demonstration that the Coda cx1 sensor unit, markers and marker drive boxes meet all hardware functionality, interfacing and performance requirements within allowable tolerances in a laboratory environment.

## **1.2 Test Item Description**

The Coda system is used to track movement of infrared LED markers in 3 dimensions. The system under test comprises a Coda cx1 sensor unit, 8 markers and an externally powered 8-marker drive box. An additional marker, connected to an internally powered 8-marker drive box is used where access is restricted. The DC power and RS-422 serial connections to the sensor unit are made via a single 37 way MIL-C-38999 connector on the end bulkhead of the unit. The Coda sensor unit contains 3 cameras each of which can locate the position of markers in one angular axis. Each camera contains a 32-element photo-detector array and associated amplifiers and analog multiplexers. Signals from the cameras are digitized on a camera interface board and then transmitted to a SHARC Digital Signal Processor (Analog Devices SHARC ADSP-21065L) within the sensor unit. The markers are powered and controlled by small drive boxes, which contain circuitry and a detector, which respond to synchronizing infrared signals produced by the sensor unit. The drive boxes cause the markers to emit flashes of infrared light in a predetermined time-multiplexed sequence thereby identifying each marker to the sensor unit. The cameras in the sensor unit are arranged such that two of them are mounted at the ends of the bar shaped casing and oriented so that they are sensitive to movement in the same direction parallel with the long axis of the case (x-axis). A baseline distance of some 670mm separates these two cameras. Signals from the cameras are processed in real time by the SHARC processor which calculates the distance of the marker from the baseline (y-axis). The third camera is mounted centrally in the Sensor case and is oriented so that it is sensitive to motion at 90 degrees to the baseline (z-axis).

## **1.3 Support Item Description**

### **1.3.1 Mini Hub**

In the flight version of the system an active hub provides DC power and also contains an embedded Power PC processor for executing some of the real time data processing and control functions for the Coda cx1 units. These tests are intended to exercise the Coda cx1 units, markers and marker drive boxes under the environmental test conditions. For this purpose, an active hub is not necessary. Instead, a mini hub provides the DC power and communications link via the Coda interface cable to the Coda unit and then to the host computer via a serial cable. The mini hub contains a mains powered 12V DC supply. The DC power and RS-422 connections for the Coda sensor unit are provided via a single 37 way MIL-C-38999 connector on the hub bulkhead. The RS-422 connections are looped within the hub from the 37 way MIL-C-38999 connector to a standard 9-way D connector on the hub bulkhead. DC power supplied to the Coda cx1 unit is controlled via a switch on the hub bulkhead. The hub is also provided with a pair of 4mm sockets connected across the switch to allow the current taken by the Coda sensor unit to be routed through an

ammeter. Similarly, a pair of 4mm sockets are provided on the hub to facilitate monitoring the DC voltage supplied by the hub. To enable thermistor readings from within the Coda unit, the Coda interface cable has designated breakout wires assigned to pins 32 – 34 of the MIL-C-38999 connector.

### **1.3.2 Host PC**

The host PC controls the operating modes of the sensor unit and receives the 3D motion data from it at a rate of up to 5Mbaud via the RS-422 serial link from the hub.

The host PC is an IBM compatible running under Windows 2000 or Windows XP. Minimum specification is 800MHz, 32Mb RAM, 1Gb HD, CD, RS-422 serial port.

### **1.3.3 Test Frame**

The test frame is a device which facilitates folding the optical path between the Coda sensor unit and markers so as to achieve an optical path length of 2 meters. This is required when functional tests need to be conducted with the test items inside a thermal chamber of internal length less than 2.2 meters.

The test frame is manufactured from aluminium structural beams which form the edges of a rectangular box with internal working dimensions of 1000mm x 1000mm x 400mm. At one end of the frame, provision is made for mounting the Coda sensor unit under test together with the markers and drive boxes (which may also be under test). At the other end of the frame, a plane mirror is fixed at a distance of 1 meter from the front of the sensor unit. The light from the markers is reflected in the mirror back to the sensor unit and so covers a distance of 2 meters to reach the cameras.

The design of the test frame is detailed in CDL drawing 1-TM07-0200:0209.

### **1.3.4 Markers and Marker Drive Boxes**

The markers that are tracked by the Coda sensor unit are small infra-red light emitting diodes. The LED markers are powered from 8-marker drive boxes which contain circuitry and a detector. The drive boxes are themselves powered either externally from a 5V supply or internally with rechargeable batteries. Each drive box has 8 small sockets into which individual markers can be plugged. Each socket has a number which indicates the identity of the marker which is plugged into each socket. The markers do not intrinsically carry any particular identification, they take on the identity of whichever drive box numbered socket they are plugged into.

### **1.3.5 Marker Disc**

The functional tests require markers to be moved through a circular path of diameter greater than 100mm in the x-z plane. This is facilitated by the marker disc which consists of a 155mm diameter aluminium disc rotated at a constant 50 rpm by a synchronous motor. Two markers and a marker drive box are attached to the disc using clips.

The design of the marker disc is detailed in CDL drawing 1-TM07-0100:0209.

## **2. Requirements**

### **2.1 Context**

This procedure supports the activities contained in the Vibration Test Procedure (CDL 1-TP07-0300:0209), Thermal Cycle Test Procedure (CDL 1-TP07-0200:0209) and EMI/EMC Test Procedure (CDL 1-TP07-0400:0209).

### **2.2 List of Hardware Under Test**

Coda cx1 sensor unit  
Externally powered 8-marker drive box  
8 markers

### **2.3 List of Support Hardware Items**

Internally powered 8-marker drive box complete with 1 marker  
9 internally powered 2-marker drive boxes complete with 9 markers  
Mini hub adapted for current and voltage monitoring  
Host PC with RS-422 serial card  
Power supply for marker drive boxes  
Power supply for adapted mini hub  
Coda interface cable  
Serial cable  
Calibration test rig (Required for science tests only)  
Test frame (Required for thermal tests only)  
Digital multi-meter  
Rigid test object (Required for mounting markers in science tests only)  
Marker disc

### **2.4 List of Software Requirements**

Coda Motion Analysis Software V6.56  
Coda cx1 calibration files  
Coda cx1 configuration file  
SHARC DSP system file V3.02

### **2.5 List of Additional Documentation**

5 Copies of the Coda cx1 Short Form Functional Test Procedure (CDL 1-TP07-0100:0208)

### **3. Configuration**

#### **3.1 General Constraints**

Electrostatic discharge (ESD) protection procedures per MIT 99-01003 shall be observed.

Connector mating/demating procedures per MIT 99-03002 shall be observed. Except that a mate/demate log will not be required.

#### **3.2 Test Configuration**

The 3D field of view of the Sensor Unit starts approximately 1.5 meters from the sensor unit (y-axis) and expands in the x and z directions as the distance y increases. The maximum range of the system is approximately 7 meters.

For the thermal tests, which may require use of a test chamber smaller than the minimum working field of view of the sensor unit, the test frame is required. (See Section 1.3.3)

When using the test frame the test configuration is as specified in CDL 1-TM07-0200:0209 and CDL 1-TM07-0400:0211

When the test frame is not required for purposes of cramming everything into the thermal test chamber the test configuration may optionally still use the test frame in the above configuration. Alternatively the test may be conducted with items configured as per CDL 1-TM07-0300:0211.

## 4. Procedures

Administrative information for this test is to be recorded in the space provided in Section 4.1. In addition, the test conductor may annotate the procedures to more accurately document the course of the test whether routine or anomalous. The following pages, plus test data generated by the host PC, will be attached to the test report which is completed every time this test is conducted. The test conductor is assumed to have reasonable familiarity and competence in navigating through software applications which observe standard Windows conventions.

### 4.1 Identification of Equipment and Personnel

Coda cx1 sensor unit \_\_\_\_\_

8 Coda markers \_\_\_\_\_

Coda externally powered 8-marker drive box \_\_\_\_\_

Test Conductor \_\_\_\_\_

Test Date \_\_\_\_\_

Test Location \_\_\_\_\_

QA Representative \_\_\_\_\_

Other individuals \_\_\_\_\_

Coda Motion Analysis software version \_\_\_\_\_

SHARC DSP system file version \_\_\_\_\_

## 4.2 Prepare Equipment

### 4.2.1 Verify Pin Connections

First ensure that no power is applied to any of the test or support items.

Using the continuity check function on the multi-meter, verify the correct shield, case and ground connections in the 37 way MIL-C-38999 connector on the Coda cx1 sensor unit. The following conditions should apply.

Pins 1 and 2 connected together. Pins 4 and 5 connected together. See Pin-out definition in Appendix 1.

Pin	yes/no	Time	Initial
<b>1 and 2 connected</b>			
<b>4 and 5 connected</b>			

Pins 8, 11, 14, 17, 23 and 37 are all connected to the Coda cx1 chassis but not connected to Pins 4 or 5 (12V return). See Pin-out definition in Appendix 1.

Pin	Connected to Chassis? (yes/no)	Open to pins 4 and 5 (>100Kohms)? (yes/no)	Time	Initial
<b>8</b>				
<b>11</b>				
<b>14</b>				
<b>17</b>				
<b>23</b>				
<b>37</b>				

If the answers above are not all 'yes' then the test cannot proceed, and power must not be applied. Please seek further assistance.

Before applying power to any test or support item, connect cables in the following sequence:

With the mini hub mains switch in the off position, connect the mains cable to the hub. Next, with the DC power switch for the Coda sensor unit on the mini hub bulkhead in the off position, connect the Coda interface cable to the mini hub. Next, verify that Pin 37 on the connector at the Coda end of the cable is connected to the chassis of the mini hub.

Pass	Fail	Time	Initial

Verify there is a high resistance connection (approximately 4.7Kohms) between the mini hub chassis and Pins 4 and 5 of the connector at the Coda end of the cable.



Pass	Fail	Time	Initial

Connect the power cables to the host PC and monitor.

Connect the serial RS-422 cable between the host PC and the mini hub.  
Connect the Coda interface cable to the Coda sensor unit.

### 4.3 Short Form Functional Test

Perform the Coda cx1 Short Form Functional Test (CDL 1-TP07-0100:0208), and attach the completed document to this report.

Pass	Fail	Time	Initial

This series of tests verifies the primary functionality and interfacing of the hardware. The remaining tests demonstrate that the hardware meets the full functionality and performance requirements within allowable tolerances.

### 4.4 Verify Reset Line

The reset line on the Coda cx1 system will be tested.

Configure the test hardware as shown in CDL 1-TM07-0300:0211. Launch and configure the software as described in Section 4.3.4 of the Short Form Test but on this occasion select the setup file:

*Reset Line Test.stp*

From the **CODA** menu select **Display Marker Positions**. This operation will cause the Coda unit to strobe. Whilst the unit is strobing, press the reset switch located on the Coda interface cable. The following error message will appear: CODA Timeout error [65535].

(If no error message appears, then the reset line is faulty and the test is failed. Please seek further assistance).

Click **OK**.

Exit the Coda Motion Analysis Software by clicking the exit **X** at top right of the screen and then re-launch the software.

If Coda software and hardware are correctly initialized a message box will appear indicating **dsp version nn.yy initialized OK**. Click the **OK** button.

The system is deemed to have passed this test if the Coda Motion Analysis software re-launches without error, as described in Section 4.3.4 of the Short Form Test.

If the Coda Motion Analysis Software does not re-launch without error, as described in Section 4.3.4 of the Short Form Test, then the system is deemed to have failed. Please seek further assistance.

Pass	Fail	Time	Initial

#### 4.5 Hardware Power Combinations

The Coda cx1 system will be exercised at its lower and upper limits of DC power input voltage.

##### 4.5.1 Low DC Power Input Voltage

Amend a copy of the Coda cx1 Short Form Functional Test Procedure:

In Section 4.2.1 replace existing text with the following:

Remove the mains power cable from the mini hub. Connect the DC power supply leads to the 4mm input sockets (Black/Yellow) on the back panel of the mini hub. Set the current limit for the DC supply to 1.2A and set the DC voltage to 10V.

In Section 4.2.2 replace existing text with the following:

Before applying power to any test or support item, connect cables in the following sequence:

With the DC power switch for the Coda sensor unit on the mini hub bulkhead in the off position, connect the Coda interface cable to the mini hub. Next, verify that Pin 37 on the connector at the Coda end of the cable is connected to the chassis of the mini hub.

Pass	Fail	Time	Initial

Verify there is a high resistance connection (approximately 4.7Kohms) between the mini hub chassis and Pins 4 and 5 of the connector at the Coda end of the cable.

Pass	Fail	Time	Initial

Connect the power cables to the host PC and monitor.  
Connect the serial RS-422 cable between the host PC and the mini hub.

Connect the Coda interface cable to the Coda sensor unit.

In Section 4.3.2 replace existing text with the following:

With the DC power supply connected to the 4mm input sockets (Black/Yellow) on the mini hub back panel switch on the DC power on the front panel of the mini hub. This will apply DC power to the Coda sensor unit. Record the current reading within the first minute after applying power.

With the DC input power supply voltage set to 10V, run the Short Form Functional Test Procedure as edited.

<b>Input Voltage</b>	<b>Pass</b>	<b>Fail</b>	<b>Time</b>	<b>Initial</b>

#### **4.5.2 High DC Power Input Voltage**

Amend a copy of the Coda cx1 Short Form Functional Test Procedure:

In Section 4.2.1 replace existing text with the following:

Remove the mains power cable from the mini hub. Connect the DC power supply leads to the 4mm input sockets (Black/Yellow) on the back panel of the mini hub. Set the current limit for the DC supply to 1.2A and set the DC voltage to 14V.

In Section 4.2.2 replace existing text with the following:

Before applying power to any test or support item, connect cables in the following sequence:

With the DC power switch for the Coda sensor unit on the mini hub bulkhead in the off position, connect the Coda interface cable to the mini hub. Next, verify that Pin 37 on the connector at the Coda end of the cable is connected to the chassis of the mini hub.

<b>Pass</b>	<b>Fail</b>	<b>Time</b>	<b>Initial</b>

Verify there is a high resistance connection (approximately 4.7Kohms) between the mini hub chassis and Pins 4 and 5 of the connector at the Coda end of the cable.

<b>Pass</b>	<b>Fail</b>	<b>Time</b>	<b>Initial</b>

Connect the power cables to the host PC and monitor.

Connect the serial RS-422 cable between the host PC and the mini hub.

Connect the Coda interface cable to the Coda sensor unit.

In Section 4.3.2 replace existing text with the following:

With the DC power supply connected to the 4mm input sockets (Black/Yellow) on the mini hub back panel switch on the DC power on the front panel of the mini hub. This will apply DC power to the Coda sensor unit. Record the current reading within the first minute after applying power.

With the DC input power supply voltage set to 14V, run the Short Form Functional Test Procedure as edited.

<b>Input Voltage</b>	<b>Pass</b>	<b>Fail</b>	<b>Time</b>	<b>Initial</b>

#### **4.6 Extended Science Tests**

The following tests exercise the Coda system to demonstrate all performance requirements.

Test 1 is designed to assess the static resolution of the 3D measurements, as a function of position within the workspace.

Test 2 is designed to test and verify the absolute accuracy within the workspace in a repeatable manner. A total of 10 test scans will be performed prior to environmental testing to define the tolerable limits against which the Coda unit will be assessed. Subsequent runs will only require a single test scan per Coda orientation to verify performance.

##### **4.6.1 Test 1 – Static Markers**

Configure the test hardware as shown in CDL 1-TM07-0300:0211. Define a working volume as a cube, 2 meters on each side as described in Appendix 2.

Launch and configure the software as described in Section 4.3.4 of the Short Form Test but on this occasion select the setup file:

*Science Test 1.stp*

Place a single marker and associated drive box at the extremities of the working volume and one at the center (see Appendix 2). Ensure the optical axis of each marker and drive box is pointing in the general direction of the sensor unit and its three cameras. Acquire 5 seconds of data at 200Hz for all 9 markers simultaneously. Save the Motion Date File as per the Short Form Test, Section 4.4.4.

The system is deemed to have passed this test if the position variation characterised by the standard deviation (std.dev.) value is less than 0.5mm in any direction. This will be calculated during post-processing. Sample graphs with interpretation are given in Appendix 3.

Filename	Time	Initial

Marker	Pass	Fail	std.dev.	Initial
1				
2				
3				
4				
5				
6				
7				
8				
9				

#### 4.6.2 Test 2 – Dynamic Markers (Absolute Accuracy - Test and Verification)

Configure the test hardware as described in CDL 1-TM07-0300:0211. Mount the Coda sensor unit at the near position, horizontally on the calibration rig, angled as shown in Appendix 4. Ensure the unit is elevated approximately 1m above ground level. Define a 2m x 2m workspace approximately 1.5m in front of the Coda unit. Attach 4 markers and associated internally powered drive box(es) to the rigid test object, approximately 300mm apart, using double sided adhesive tape. Position the object in the near left corner of the workspace and ensure the optical axis of each marker and drive box is parallel to the Coda y-axis.

Launch and configure the software as described in Section 4.3.4 of the Short Form Test but on this occasion select the setup file:

*Science Test 2.stp*

Move the Coda unit a distance of 2.8m away from the rigid test object whilst acquiring 30 seconds of data at 200Hz. The calibration rig employs a set of trolley rails to facilitate such movements in a repeatable manner over a given distance. Return the Coda unit to the near measurement position.

Save the Motion Date File as per the Short Form Test, Section 4.4.4. Repeat the described data acquisition process a further 4 times such that a total of 5 files are collected. (Note: only 1 test required for subsequent verification).

Filename	Time	Initial

Filename	Time	Initial

Filename	Time	Initial

Filename	Time	Initial

Filename	Time	Initial

Rotate the Coda unit 180 degrees about its y-axis and re-mount the unit on the calibration rig as described earlier. With the Coda at the far measurement position, move the unit a distance of 2.8m along the trolley rails towards the rigid test object whilst acquiring 30 seconds of data at 200Hz. Return the Coda unit to the far measurement position.

Save the Motion Date File as per the Short Form Test, Section 4.4.4. Repeat the described data acquisition process a further 4 times such that a total of 5 files are collected. (Note: only 1 test required for subsequent verification).

Filename	Time	Initial

Filename	Time	Initial

Filename	Time	Initial

Filename	Time	Initial

Filename	Time	Initial

In post-processing, the variability of the distance between pairs of markers as a function of Coda position along the trolley rail will be calculated. The two sets of 5 scans will be used to define the tolerable limits against which the unit will be measured.

During the subsequent verification, the system is deemed to have passed this test if the inter-marker distances vary less than the tolerable limits.

Marker Pairs	Tolerable Limits	Pass	Fail	Initial
1-2				
1-3				
1-4				
2-3				
2-4				
3-4				

## 4.7 Ambient Illumination

The following test is designed to assess the Coda system for ambient illumination interference.

### 4.7.1 Test Configuration and System Set-up

Configure the test hardware as shown in CDL 1-TM07-0300:0211 and define a working volume as a cube, 2 meters on each side as described in Appendix 2.

Launch and configure the software as described in Section 4.3.4 of the Short Form Test but on this occasion select the setup file:

*Ambient Test.stp*

Place a single marker and associated drive box at the extremities of the working volume and one at the center (see Appendix 2). Ensure the optical axis of each marker and drive box is pointing in the general direction of the sensor unit and its three cameras.

Turn off all lights in the test studio.

From the *Coda* menu select **Display Marker Positions**. A dialog box will appear showing the positions of markers 1-9 in mm. Record all marker positions in the table below (x,y,z for OFF).

Now turn on the test studio lighting (12 x 6 ft fluorescent tubes 240V, 50Hz, 60W).

Record all marker positions in the table below (x,y,z for ON).

The system is deemed to have passed this test if the difference between pairs of readings (Lights on/off) is less than 0.5mm.

Position	X		Y		Z		Pass	Fail	Initial
	ON	OFF	ON	OFF	ON	OFF			
Lights									
Marker 1									
Marker 2									
Marker 3									
Marker 4									
Marker 5									
Marker 6									
Marker 7									
Marker 8									
Marker 9									

## **5. Test Operator Information**

### **5.1 In the Event of Test Failure**

Problems are covered in a similar section of the Short Form Test Procedure so are not repeated here.



## **6. Appendices**

Appendix 1: Pin-out for Coda Unit using 37 way MIL-C-38999 Connector

Appendix 2: Definition of the Working Volume for Static Marker Analysis

Appendix 3: Sample Graphs and Interpretation for Static Marker Analysis

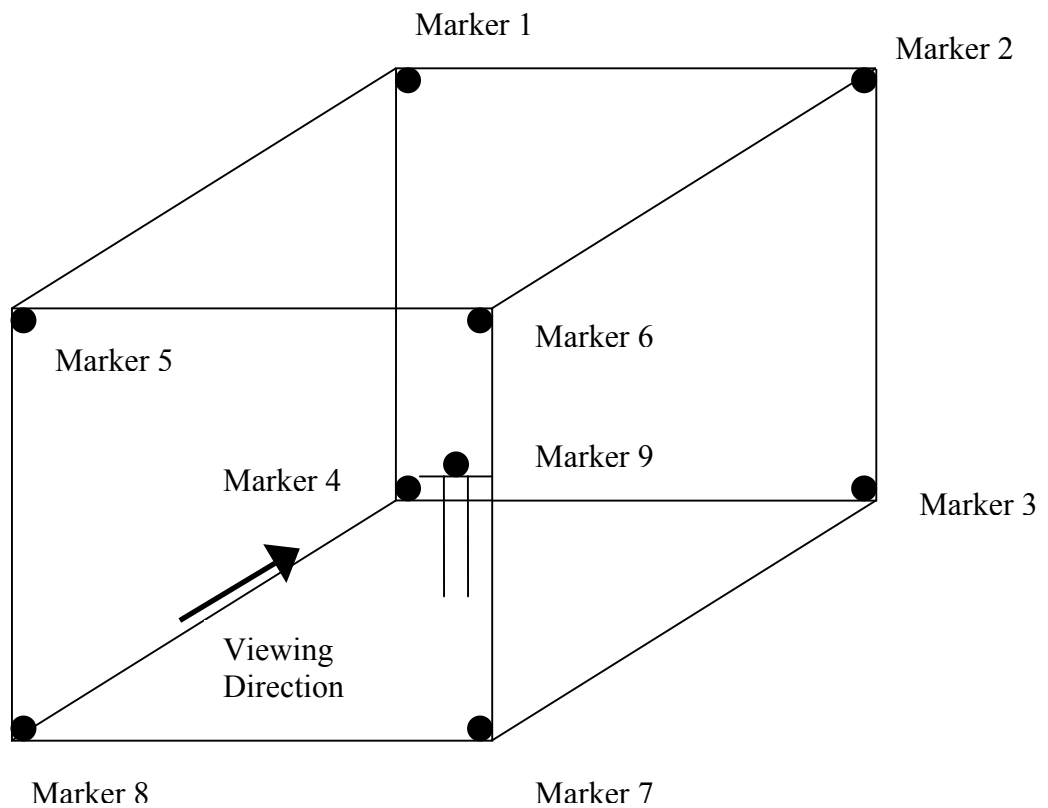
Appendix 4: Dynamic Marker Analysis Test Configuration

## Appendix 1: Pin-out for Coda Unit using 37 way MIL-C-38999 Connector

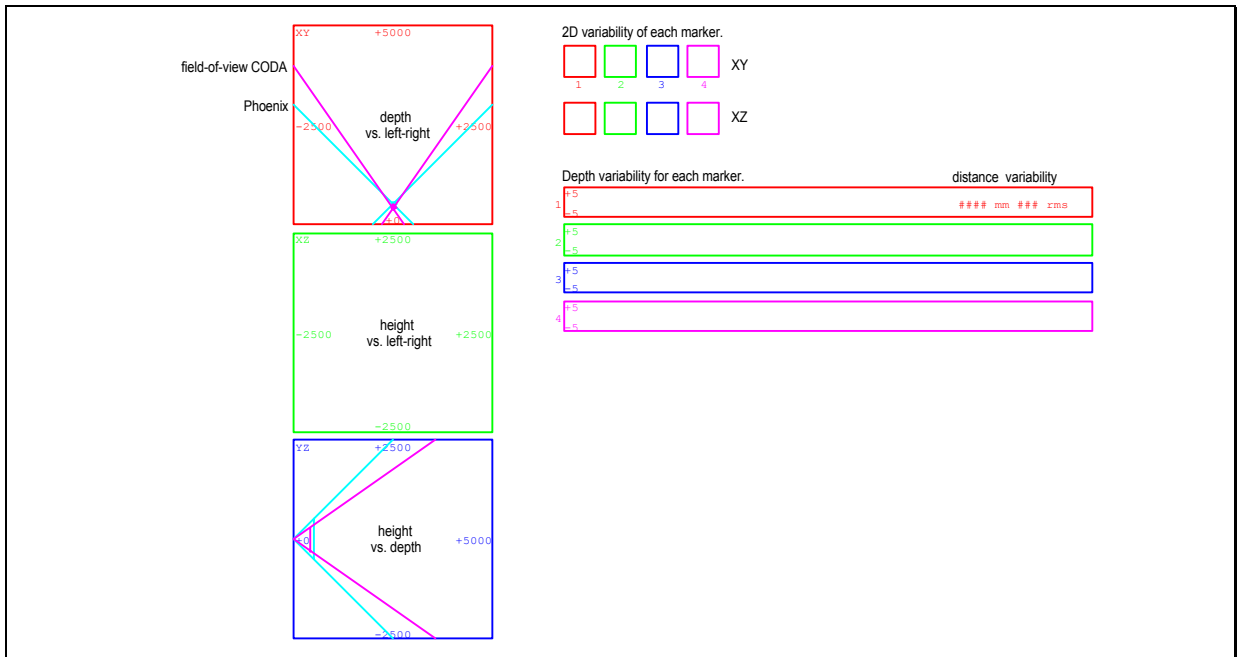
Pin #	Function
1	+12VDC (A)
2	+12VDC (B)
3	nc
4	+12 Rtn (A)
5	+12 Rtn (B)
6	RS422 +Data
7	RS422 -Data
8	Data Shield
9	RS422 +Cmd
10	RS422 -Cmd
11	Cmd Shield
12	RS422 +RTS
13	RS422 -RTS
14	RTS Shield
15	RS422 +CTS
16	RS422 -CTS
17	CTS Shield
18	nc
19	nc
20	nc
21	+Sync In
22	-Sync In
23	SyncI Shield
24	(reserved) +Sync Out
25	(reserved) -Sync Out
26	(reserved) SyncO Shield
27	(reserved) +Strobe Out
28	(reserved) -Strobe Out
29	(reserved) Strobe Shield
30	+SHARC_RESET
31	-SHARC_RESET
32	Wall Thermistor
33	Thermistor Common
34	SHARC Thermistor
35	nc
36	nc
37	Chassis

## Appendix 2: Definition of the Working Volume for Static Marker Analysis

The working volume for the static marker analysis is a cube, 2 meters on each side. Lightweight aluminium structural beams are bolted together to define the cube. At the extremities of the working volume (aluminium cube), markers and their associated internally powered marker drive boxes are attached using clips and double sided adhesive tape. A further marker and drive box is positioned on a stand in the center of the working volume. The general set-up is shown below.



## Appendix 3: Sample Graphs and Interpretation for Static Marker Analysis



### Interpretation

#### Left Display

Panels on the left side show the workspace from three different views. Marker positions are shown as dots (none shown here) indicating the position of each static marker within the working volume. Diagonal lines indicate the limits of the workspace for each unit. The intersection of the two lines in the XY plane indicates the closest possible position of a marker to the cameras. In the YZ plane, this position is indicated by a short vertical line connecting the two diagonals. In the XZ plane, the limits of the workspace depend on the depth and so are not shown.

#### Upper Right Display

Variations of each marker position around the mean are shown on an expanded scale ( $\pm 5\text{mm}$ ).

#### Lower Right Display

Variations in the Y measurement vs. time are shown for each marker on an expanded scale ( $\pm 5\text{mm}$ ). Numbers to the right of each plot indicate the average distance of the marker from the camera and the variability in the Y component.

**Appendix 4: Dynamic Marker Analysis Test Configuration**

