Honeywell

Laser Caliper Sensor

User Manual

6510020216 – Rev 01

Laser Caliper Sensor

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Contents

Introduction ... ix

Audience ... ix

About this manual ... ix

Conventions ... x

Honeywell, Vancouver operations part numbers ... xii

Figures in this manual ... xii

1. System Overview ... 1-1

1.1. Introduction ... 1-1

1.2. Measurement overview ... 1-2

1.3. Hardware description ... 1-6

1.3.1. Component overview ... 1-6

1.3.1.1. Laser triangulation ... 1-6

1.3.1.2. Inductive distance sensing ... 1-7

1.3.2. Calibration module ... 1-9

1.3.2.1. Calibration-module electronics ... 1-15

1.3.3. Z-sensor module ... 1-17

1.3.3.1. Z-module electronics ... 1-21

1.3.4. Alignment tool hardware description ... 1-23

1.4. Da Vinci signal family description ... 1-24

1.5. Safety notes and interlock description ... 1-27

1.5.1. Gauge radiation certification and safety notes ... 1-27

1.5.2. Laser interlock ... 1-28

2. Gauge Functional Basics ... 2-1

2.1. Measurement range ... 2-1

2.2. Calibration function and lookup table generation ... 2-3

2.3. Standardization 2-6

3. Gauge Installation and Setup 3-1

3.1. Pre-gauge arrival activity 3-1
3.1.1. Decide which NCC module to install in which scanner head............ 3-1
3.1.2. Prepare the scanner to provision compressed air to the NCC gauge 3-2
3.1.3. Ensure Da Vinci software is up to date 3-6
3.1.4. Install keyswitch elements............ 3-6

3.2. Gauge commissioning............ 3-7
3.2.1. Mechanical installation 3-7
3.2.2. Electrical installation, power up, and basic commissioning............ 3-8
3.2.2.1. Verify all system temperatures are in range............ 3-10
3.2.2.2. Execute a nominal calibration to ensure all displacement measuring devices are functional............ 3-12
3.2.2.3. Check gauge stability and flag toggling repeatability............ 3-13
3.2.2.4. Verify temperature stability 3-15
3.2.2.5. Perform flag scans 3-16
3.2.3. How to determine the optimum on sheet position for the dome 3-16
3.2.4. Likely profiles for z-module laser, calibration-module laser, z-sensor, and LVDT............ 3-18
3.2.5. How alignment and sheet position influence measurement quality 3-19
3.2.6. Optimize sheet shape and estimate optimum measurement position............ 3-23
3.2.6.1. Optimization of angle by dome position 3-28
3.2.6.2. To mutually align lasers using alignment tool............ 3-29
3.2.7. How to set the static-offset to report the proper absolute value............ 3-37
3.2.8. Collect scanner baseline information............ 3-37

4. Da Vinci Software Description 4-1

4.1. Laser caliper measurements............ 4-2

4.2. Setup display 4-2
4.2.1. Coanda flow setup............ 4-3
4.2.2. Lookup table setup 4-4
4.2.3. Dome movement setup............ 4-5
4.2.4. Flag correction............ 4-6
4.2.5. Measurement offsets............ 4-6
4.2.6. LVDT correction............ 4-7
4.2.7. ODP correction............ 4-8
4.2.8. Recipe enabled options 4-8

4.3. Calibration maintenance display............ 4-8

4.4. Calibration display 4-15

4.5. Compare calibration sets display 4-21

4.6. Dome control setup display 4-21
4.7. Profile Correction display 4-22
4.8. Sensor setup 4-24

5. Calibration 5-1
5.1. Calibration overview 5-1
5.2. Calibration setup 5-2
5.3. Calibration Procedure 5-2

6. Maintenance 6-1
6.1. Maintenance schedule 6-1
6.2. Safely splitting scanner heads when laser caliper installed 6-2
6.3. Inspecting standardize report 6-2
6.4. Cleaning triangulation sensor windows 6-7
6.5. Checking calibration 6-8
6.6. Cleaning under CML dome and ZML dust cover 6-9
6.7. Cleaning the air clamp slot 6-9
6.8. Checking air tubes and air pressures 6-9
6.9. Checking head-split interlock 6-9

7. Troubleshooting 7-1
7.1. Functional failure troubleshooting 7-2
7.1.1. Suspected failure of interlock system 7-2
7.1.2. Suspected laser triangulation unit failure 7-3
7.1.3. Suspected failure of laser triangulation temperature control system 7-5
7.1.4. Suspected z-sensor failure 7-6
7.1.5. Suspected failure of z-sensor temperature control system 7-6
7.1.6. Problems moving the calibration head dome, reaching the retract limit, or initialization error 7-7
7.1.6.1. Stepper motor failure 7-8
7.1.6.2. Retract limit not reached 7-9
7.1.6.3. Insert limit not reached 7-9
7.1.7. Suspected PCBA, connector, or power track failure 7-10
7.1.8. Staging error 7-11
7.1.9. Flag failure 7-11
7.2. Performance failure troubleshooting (measurement present but of poor quality) 7-12
7.2.1. Absolute value drift 7-12
7.2.2. Profile error 7-13
7.2.2.1. Profile correlates with x or y profile 7-15
7.2.2.2. Profile correlates with head separation profile 7-18

7.2.2.3. Errors correspond with maxima in head separation 7-22
7.2.2.4. Profile correlates with calibration module laser profile 7-22
7.2.2.5. Calibration error resulting in profile errors 7-24

8. Storage, Transportation, and Disposal 8-1
8.1. Storage and transportation environment 8-1
8.2. Disposal 8-1

9. Documentation 9-1

10. Glossary 10-1

List of Figures

Figure 1-1 Basic uncorrected NCC measurement 1-3
Figure 1-2 Basic NCC measurement, including LVDT measurement to account for dome movements 1-4
Figure 1-3 Principle of laser triangulation 1-7
Figure 1-4 Principle of inductive distance measurement 1-8
Figure 1-5 Principle of air clamp operation 1-8
Figure 1-6 Laser misalignment leads to measurement error 1-9
Figure 1-7 Calibration module part detail (1/3) 1-10
Figure 1-8 Calibration module part detail (2/3) 1-11
Figure 1-9 Calibration module part detail (3/3) 1-13
Figure 1-10 Calibration module part identification 1-14
Figure 1-11 Calibration-module triangulation laser and LVDT mounted on translation bracket 1-15
Figure 1-12 Layout of calibration-module PCBA (6581500002). The test points and LEDs are in the lower right hand quarter 1-16
Figure 1-13 Z-sensor module part detail (1/2) 1-18
Figure 1-14 Z-sensor module part detail (2/2) 1-19
Figure 1-15 Z-sensor triangulation device and z-sensor coil form attached to aluminum translation plate 1-20
Figure 1-16 Z-sensor module purge arrangement. The laser fits between the two side pieces and over the circular coil-form insert 1-21
Figure 1-17 Layout of z-module interface PCBA (6581500001). The test points are in the middle of the bottom edge 1-22
Figure 1-18 Alignment tool part identification 1-23
Figure 1-19 MSS Setup Diagnostics 1-24
Figure 1-20 MSS Job Set IO Point Monitor 1-25

Figure 1-21 Generalized interlock schematic 1-30
Figure 1-22 Interlock schematic for configuration with z-module in upper head and calibration module in the lower head 1-31
Figure 1-23 Interlock schematic for calibration module in upper head and z-module in lower head 1-32
Figure 1-24 Interlock schematic for config G board set 1-33
Figure 2-1 Measurement overlap range, deadbands and typical dome positions 2-2
Figure 2-2 Overlap range as influenced by scanner sheet gap 2-3
Figure 3-1 Air layout for scanner with large gauge population 3-3
Figure 3-2 Modifications to endbell manifold to route third air line 3-4
Figure 3-3 Modified manifold and the scanner head (6580700609) 3-5
Figure 3-4 Air clamp module installed with step upstream of measurement hole 3-8
Figure 3-5 Expected temperatures and temperature voltages 3-10
Figure 3-6 Review calibration slopes: A1 is the slope and A0 is the offset 3-13
Figure 3-7 Repeated reference setup 3-14
Figure 3-8 Results of repeated standardize (flag toggling) 3-15
Figure 3-9 Laser caliper profile measuring on flag 3-16
Figure 3-10 Overlap range plot generated from *6510030033PT01.xls* 3-17
Figure 3-11 How misalignment and non-flat sheet lead to caliper measurement error 3-20
Figure 3-12 Example of insufficient air flow through air clamp 3-22
Figure 3-13 Actual sheet positioning influence of air clamp on production sheet 3-23
Figure 3-14 Example of 3-D sheet topology over air clamp 3-24
Figure 3-15 Securing and repositioning screws for calibration module alignment 3-27
Figure 3-16 MD cross section of sheet topology 3-28
Figure 3-17 Sign of sheet angle relative to the ideal measurement position 3-28
Figure 3-18 Example of sheet angle relationship to profile quality 3-29
Figure 3-19 Controls and indicators on alignment tool (PSD extension not shown). 3-32
Figure 3-20 Z-module alignment provisioning mechanics 1/2 3-34
Figure 3-21 Z-module alignment provisioning mechanics 2/2 3-35
Figure 3-22 Close-up of translating dish and attached measurement devices 3-36
Figure 4-1 Laser caliper software display in Da Vinci 4-1
Figure 4-2 NCC Setup display 4-3
Figure 4-3 Example of misleading slope reported by Da Vinci due to deadband included in fit range 4-5
Figure 4-4 NCC Calibration Maintenance Display 4-10
Figure 4-5 Entering a LUT for LVDT 4-11
Figure 4-6 Selects raw calibration data file to generate an LUT 4-12
Figure 4-7 Graph of LUT nonlinearity generated from raw calibration data file 4-12
Figure 4-8 Entries updated in Trial Cal fields 4-13
Figure 4-9 Select apply to all when associating LUTs with pointers 4-14
Figure 4-10 A0 and A1 updated after values stored to working and recipe calibrations 4-15
Figure 4-11 NCC calibration display 4-16

Figure 4-12 NCC calibration setup display 4-17
Figure 4-13 Calibration in progress 4-19
Figure 4-14: Saving sensor calibration data to file. 4-20
Figure 4-15 NCC Dome control display 4-21
Figure 4-16 NCC Profile correction display 4-23
Figure 4-17 Example location of Bkgd phase and Check limits flags for laser caliper 4-26
Figure 6-1 Example standardize displacements over time 6-5
Figure 6-2 Example chart of calculated standardize quantities over time 6-6
Figure 6-3 Example standardize flag values over time 6-7
Figure 7-1Example of triangulation laser problem 7-5
Figure 7-2 MSS Setup Diagnostics Display 7-8
Figure 7-3 Basic uncorrected NCC measurement 7-14
Figure 7-4 Caliper error looks like X (CD) profile of scanner head wander 7-15
Figure 7-5 Correlation demonstrates that error is very likely a relationship with CD scanner geometry 7-16
Figure 7-6 Caliper error looks like Y (MD) profile of scanner head wander 7-17
Figure 7-7 Correlation - error is very likely related to MD scanner geometry 7-18
Figure 7-8 Caliper error "looks like" vertical head separation 7-20
Figure 7-9 Correlation - caliper error due to lack of z-sensor/z-module laser cancellation.... 7-20
Figure 7-10 Caliper error correlated with calibration head laser displacement 7-23
Figure 7-11 Caliper error correlates with calibration head laser displacement function 7-23
Figure 9-1 6509421301: laser caliper sensor top-level assembly 9-2
Figure 9-2 6581800031: laser caliper sensor cal-module assembly (1/ 6) 9-3
Figure 9-3 6581800031: laser caliper sensor cal-module assembly (2/6) 9-4
Figure 9-4 6581800031: laser caliper sensor cal-module assembly (3/6) 9-5
Figure 9-5 6581800031: laser caliper sensor cal-module assembly (4/6) 9-6
Figure 9-6 6581800031: laser caliper sensor cal-module assembly (5/ 6) 9-7
Figure 9-7 6581800031: laser caliper sensor cal-module assembly (6/ 6) 9-8
Figure 9-8 6581800032: laser caliper sensor z-module assembly (1/5) 9-9
Figure 9-9 6581800032: laser caliper sensor z-module assembly (2/5) 9-10
Figure 9-10 6581800032: laser caliper sensor z-module assembly (3/5) 9-11
Figure 9-11 6581800032: laser caliper sensor z-module assembly (4/5) 9-12
Figure 9-12 6581800032: laser caliper sensor z-module assembly (5/5) 9-13

List of Tables

Table 1-1 Calibration-module PCBA electrical test point and LED identification 1-16
Table 1-2 z-module interface PCBA (6581500001) electrical test point and LED identification.. 1-22
Table 1-3 NCC signal complement 1-26

Table 2-1 Lookup table format 2-4
Table 3-1 NCC harness p/ns for use with Config F and G boardsets 3-9
Table 3-2 Installation steps and time estimates 3-38
Table 4-1 Calibration file column identification 4-21
Table 4-2 Da Vinci setup settings 4-24
Table 5-1 Initial settings for calibrations and lookup table generation 5-2
Table 6-1 Expected standardize values and spreads based on 100 entry standardize report.... 6-3
Table 7-1 Functional failure troubleshooting 7-1
Table 7-2 Performance failure troubleshooting. 7-2
Table 7-3 Staging error codes and interpretation 7-11
Table 9-1 SP09421301: Laser Caliper Spares List 9-14

List of Equations

Equation 1-1 Basic NCC computation 1-3
Equation 1-2 LVDT-corrected caliper relationship 1-5
Equation 2-1 LVDT displacement/signal relationship 2-4
Equation 2-2 Simplified LVDT displacement/signal relationship 2-4
Equation 2-3 Determination of LUT index for a measurement 2-5
Equation 4-1 Caliper relationship with flag corrector active 4-6
Equation 4-2 Caliper relationship with flag corrector active 4-7
Equation 4-3 Caliper relationship with LVDT corrector active. 4-7
Equation 4-4 ODP calculation. 4-8
Equation 7-1 Repeated basic caliper relationship 7-19
Equation 7-2 Caliper error equivalent to z-module laser profile if the laser is completely obscured 7-19
Equation 7-3 Caliper error profile correlates positively with z-module laser displacement if laser under-reports variation 7-19
Equation 7-4 Caliper error will be positively proportional to the calibration head laser displacement function if the calibration head laser is under-reporting displacements ... 7-24

Introduction

This manual provides an introduction to the laser (non-contacting) caliper sensor and detailed instructions for its installation, operation, and troubleshooting.

Audience

This manual is intended for use by engineers, process engineers, and field service specialists. It assumes that the reader has some knowledge of the operation of a paper machine and a basic understanding of mechanical, electrical and computer software concepts.

About this manual

This manual contains ten chapters.

Chapter 1, **System Overview**, describes an overview of the device. This is a good place to start if this is the first time you are using the gauge. The principle of the measurement is explained and the very basic relationships for caliper are defined.

Chapter 2, **Gauge Functional Basics,** describes the functional basics of the gauge working as a system, that is, what happens when a calibration is performed, what does the gauge do at standardize. There is no software "how-to" description in this section. This chapter is intended to provide an understanding of what the gauge is doing physically.

Chapter 3, **Installation and Set up,** describes issues associated with installing (or-reinstalling) the gauge into a Da Vinci scanner. This is a useful section to follow upon receipt of the sensing hardware. There is no software how-to in this section.

Chapter 4, **Da Vinci Software Description,** describes the Da Vinci displays specific to the NCC. Instructions for use of the software are provided here as well as detailed explanations for the functionality of various software correctors.

Chapter 5 **Calibration**, describes the procedure for calibration.

Chapter 6, **Maintenance**, describes common tasks for maintaining the gauge and maintenance task schedules.

Chapter 7, **Troubleshooting,** describes potential problems and suggests ways to mitigate them.

Chapter 8, **Storage, Transportation, and Disposal**, describes the conditions for storage and transport, as well as recommended disposal procedures.

Chapter 9, **Documentation**, features assembly drawings and spares list. See Figures in this manual.

Chapter 10, **Glossary,** defines terms and acronyms used in this manual.

Conventions

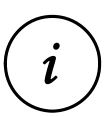
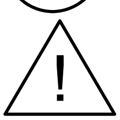
The following conventions are used in this manual:

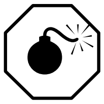
i

NOTE: Text may appear in uppercase or lowercase except as specified in these conventions.

`Boldface`
`Special Type`

Boldface characters in this special type indicate your input. Characters in this special type that are not boldfaced indicate system prompts, responses, messages, or characters that appear on displays, keypads, or as menu selections.

Italics	In a command line or error message, words and numbers shown in italics represent filenames, words, or numbers that can vary; for example, *filename* represents any filename. In text, words shown in italics are manual titles, key terms, notes, cautions, or warnings.
Boldface	Boldface characters in this special type indicate button names, button menus, fields on a display, parameters, or commands that must be entered exactly as they appear.
lowercase	In an error message, words in lowercase are filenames or words that can vary. In a command line, words in lowercase indicate variable input.
Type	Type means to type the text on a keypad or keyboard.
Press	Press means to press a key or a button.
[ENTER] or **[RETURN]**	**[ENTER]** is the key you press to enter characters or commands into the system, or to accept a default option. In a command line, square brackets are included; for example: **SXDEF 1 [ENTER]**
[CTRL]	**[CTRL]** is the key you press simultaneously with another key. This key is called different names on different systems; for example, **[CONTROL]**, or **[CTL]**.
[KEY-1]-KEY-2	Connected keys indicate that you must press the keys simultaneously; for example, **[CTRL]-C**.
Click	Click means to position the mouse pointer on an item, then quickly depress and release the mouse button. This action highlights or "selects," the item clicked.
Double-click	Double-click means to position the mouse pointer on an item, then click the item twice in rapid succession. This action selects the item "double-clicked."
Drag X	Drag X means to move the mouse pointer to X, then press the mouse button and hold it down, while keeping the button down, move the mouse pointer.
Press X	Press X means to move the mouse pointer to the X button, then press the mouse button and hold it down.
	The information icon appears beside a note box containing information that is important.
	The caution icon appears beside a note box containing information that cautions you about potential equipment or material damage.



The warning icon appears beside a note box containing information that warns you about potential bodily harm or catastrophic equipment damage.

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Honeywell, Vancouver Operations assigns a part number to every manual. Sample part numbers are as follows:

6510020004

6510020048 Rev 02

The first two digits of the part number are the same for all Honeywell, Vancouver Operations products. The next four digits identify part type. Type numbers 1002 designates technical publications. The next four digits identify the manual. These digits remain the same for all rewrites and revision packages of the manual for a particular product. Revision numbers are indicated after the Rev.

Figures in this manual

Figures depicting product diagrams or schematics are included in this manual for illustration and explanation purposes only, and may not match the revision of the drawing that is currently available. Please use Installation drawings that are

- shipped with the product,
- available from your local Honeywell representative/Technical Assistance Center,
- available at kview intranet site (Honeywell field personnel only).

1. System Overview

1.1. Introduction

The laser caliper sensor is designed to accurately measure sheet caliper online without sheet damage. The non-contacting nature of the measurement avoids wear and build-up problems and can be used for applications for which contacting caliper sensors are not suitable. Accurate and reliable caliper measurements are required to build high quality rolls, to meet product specifications, and to reduce material usage and waste.

Offline measurements of caliper are usually based on the TAPPI T411 standard. Such a measurement employs a measurement foot which presses the sheet into an anvil 16-mm in diameter at a 1 mm/s, with a force of 50 kPa, for 2 seconds. Obviously such a measurement cannot be made online on a continuous process. The most common type of online measurement employs a ferrite on one side and a bridge on the other. The magnetic inductance of the circuit gives a measurement of the caliper. Such a measurement can be affected by strong vibrations of the sheet at high speeds or dirt build-up from coatings or filler. The device can be easily damaged since the two sides of the device must be of a light-weight construction to allow it to follow the sheet movement. The contacting surfaces can wear due to abrasive ash in the sheet which can lead to incorrect measurements and can necessitate frequent replacement.

The model 4213-01 Laser Caliper is a second generation device. The 00 device had a very different design. The greatest difference is that the new device employs a linear air clamp to keep the sheet within measurement range and flat that minimizes measurement errors.

The laser caliper requires a 4000 series scanner with a 6 Pak head and a minimum of RAE 4 with update 9. Currently special scanner heads must be built with a 6-in diameter hole. This sensor is not intended for use in outboard heads.

Throughout this manual the terms laser caliper and non-contacting caliper (NCC) may be used to refer to this sensor. The official product name is Laser Caliper; however, many of the Da Vinci software displays refer to the sensor as the Non-Contacting Caliper.

1.2. Measurement overview

The NCC is a geometric sensor that measures displacements. The gauge consists of two modules: the **z module** and the **calibration module**. Depending on the specific installation site, the sensor may be installed with the z module in the upper scanner head and the calibration module in the lower scanner head, or the reverse. Both modules contain an optical triangulation sensor.

The z module contains an inductive proximity sensor (a z sensor), among other things.

The calibration module includes the patented sheet stabilizing air clamp and stepper motor driven stainless steel target (also called the dome) that enables automated refreshment of the calibrations.

In Figure 1-1, the laser caliper's z module is depicted as being mounted in the upper scanner head while the lower scanner head houses the laser caliper's calibration module. The following description is also valid if the installation is reversed.

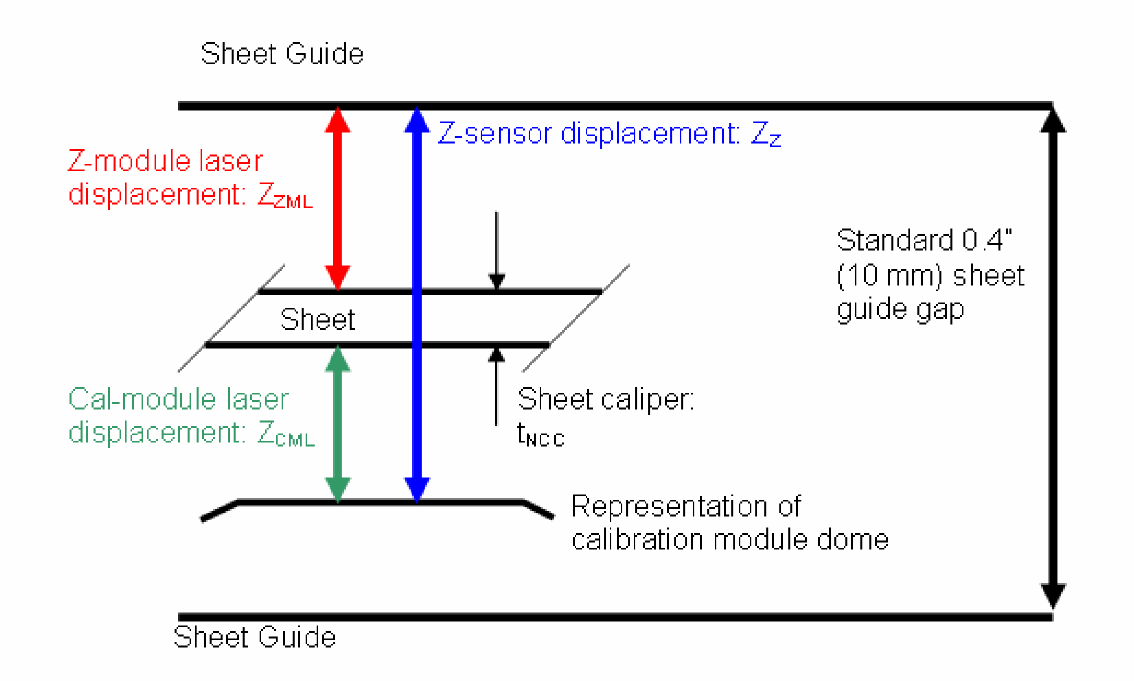

Figure 1-1 Basic uncorrected NCC measurement

The uncorrected caliper reported by the gauge is the algebraic sum of three displacements. The inductive proximity sensor (z-sensor) measures the gap between the two heads. It measures the distance between the upper sheet guide and the top surface of the stainless steel target in the calibration module, while the two laser triangulation sensors measure the distances between the upper head and the upper surface of the sheet, and the lower head and the lower surface of the sheet respectively. In this manual the two lasers and the z-sensor are called collectively the direct measurement devices because their displacements are the basis for the most simple, uncorrected caliper measurement. The sum of the laser triangulation measurements and the sheet caliper is equal to the head separation. The simplest expression for uncorrected NCC, to within a static offset Δt_o, at every CD position, **x** is expressed as $t_{NCC}(x)$,

$$t_{NCC}(x) = Z_Z(x) - Z_{ZML}(x) - Z_{CML}(x) + \Delta t_o,$$

Equation 1-1 Basic NCC computation

where $Z_Z(x)$, $Z_{ZML}(x)$, and $Z_{CML}(x)$ are, respectively, the z-sensor, z-module laser, and cal-module laser displacements at each CD position.

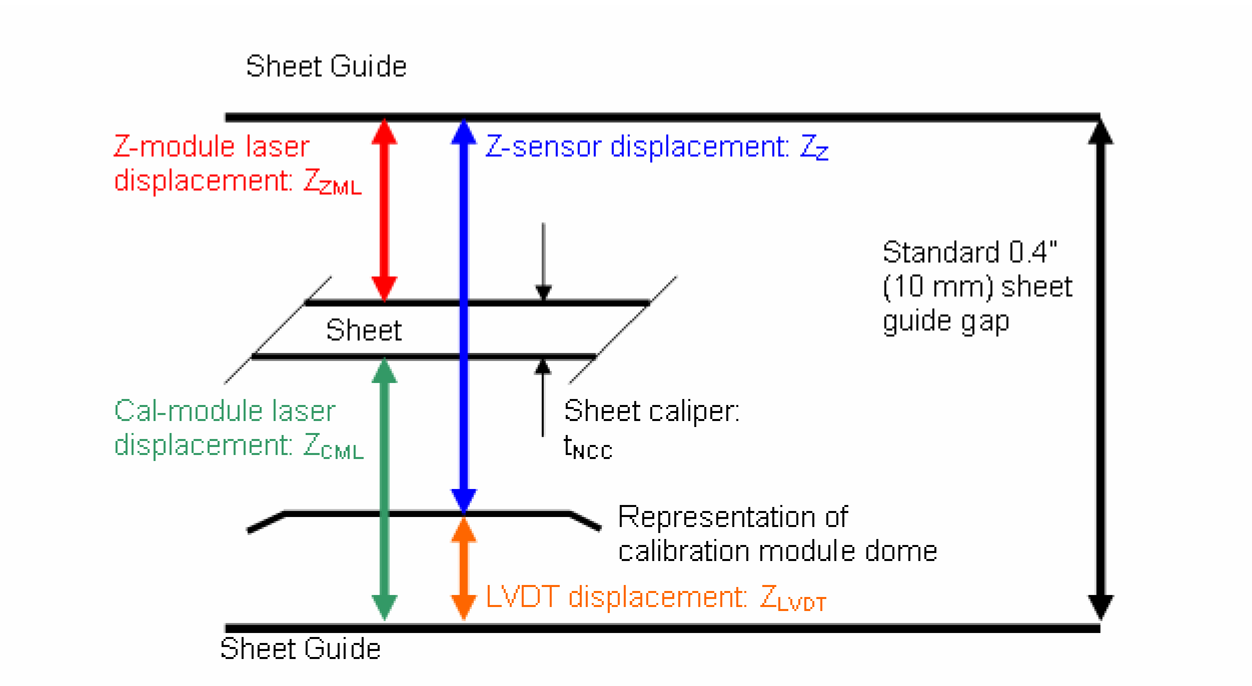

Figure 1-2 Basic NCC measurement, including LVDT measurement to account for dome movements

Each of the z-module and calibration-module lasers and the z sensor provide voltages to Da Vinci that are interpreted as displacements. The translation from voltage to displacement is done through the device's lookup table (LUT). The calibration required to update the device LUTs and the operations required to store them are described in more detail later in this manual.

The simplicity of Equation 1-1 camouflages the complexity of the gauge. In addition to the three sensors, upper and lower triangulation systems, and the z-sensor an additional sensor—an LVDT—is included to enable online calibration, to correct for thermal expansion, and to provide a reference for the dome position. Like the three direct devices, the LVDT is interpreted through a calibration relationship that provides the link between the LVDT measured voltage and the displacement that it is seeing. Unlike the direct devices, the LVDT calibration cannot be performed online in a Da Vinci system. The LVDT calibration relationship is determined outside the sensor at manufacture.

Figure 1-2 shows an additional detail of the gauge. Since the calibration module dome can move vertically in the gap and its motion is tracked by the calibration module's LVDT, it is possible to account for dome movement influences in the caliper computation. Dome movement can occur intentionally by movement of the stepper motor or unintentionally due to thermal breathing of the gauge. Refine the caliper expression as in Equation 1-2:

$$t_{NCC}(x) = \left(Z_Z(x) + Z_{LVDT}(x)\right) - \left(Z_{ZHL}(x) + Z_{CML}(x)\right) + \Delta t_o'.$$

Equation 1-2 LVDT-corrected caliper relationship

A stepper motor is present to drive a target through the operational range of the three direct sensors, to enable online calibration refreshment, and to permit a level of control over the sheet position in the gap during operation. Onboard firmware is included to parse out command signals to the stepper motor and to keep track of positional limits.

A flag toggling mechanism is included to switch from an open window through which the sheet is measured to an opaque flag on which standardizations are performed.

The gauge controls the sheet position for measurement by way of an air clamp. This air clamp applies aerodynamic forces to the sheet so the sheet presents itself in a position most desirable for measurement. A relatively high flow is required to execute this sheet positioning. The gauge includes plumbing to route the air flow through the sensor into an instrumented plenum where flow characteristics are measured and reported to Da Vinci, before the flow emerges at near sonic speeds through the patented Coanda slot[1].

An imaging optical measurement is extremely sensitive to dust. To improve the dust resistance of the gauge, both the calibration and z-modules are designed with air purges to keep the optical windows free of debris.

For temperature stability, the gauge includes three temperature controllers. Each of the mechanical cases of the upper and lower triangulation sensors is held at constant temperature through a control system actuated by a form-fitted resistive heater and instrumented by an embedded thermistor. As well, the ceramic coil-form that provides the mechanical structure for the z-sensor is temperature controlled with a pair of thermo-electric coolers.

[1] US Patent 6,936,137.

1.3. Hardware description

1.3.1. Component overview

The laser caliper measurement is based on two triangulation sensors and a z-sensor. The most important part of the sensor for operation is the air clamp that stabilizes the sheet. Some explanation of the principles of operation of these devices is provided here in order to assist with device troubleshooting and suitability of application. The top-level drawings of the sensor and the calibration and z modules are included in Chapter 9.

1.3.1.1. Laser triangulation

A laser triangulation device projects a diode-laser beam towards its target projecting a spot. This spot can then be imaged onto a position sensitive detector (PSD). Knowledge of the reflected angle and the geometry of the device is enough to calculate the distance to the sheet (see Figure 1-3). Since it uses two such devices, it is also necessary to use lasers at two wavelengths with optical filters to discriminate the two beams. It uses a PSD instead of a CCD (charge coupled device) or CMOS (complimentary metal oxide semiconductor) array so it is not limited by micron-sized pixels or pixel-to-pixel gain variations.

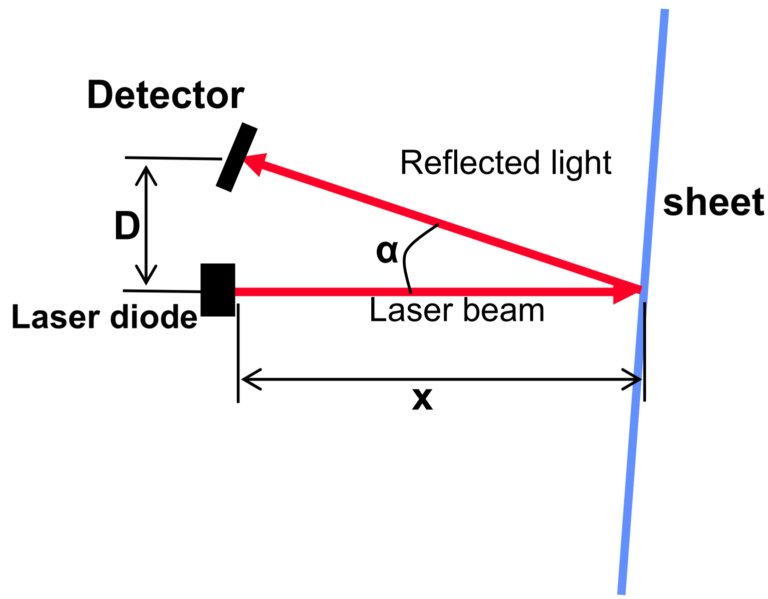

Figure 1-3 Principle of laser triangulation

1.3.1.2. Inductive distance sensing

The z-sensor drives an alternating current through a multi-turn coil. The EM field induces a current in the stainless steel target. The interaction with the target is measured as a change of inductance. This can be related to distance. This measurement is not affected by non-magnetic materials such as paper or plastic: the sensor sees right through the sheet to the dome. Since the measurement is temperature sensitive, the coil is wrapped around a highly thermally conductive Aluminum Nitride ceramic coil form which can be temperature controlled.

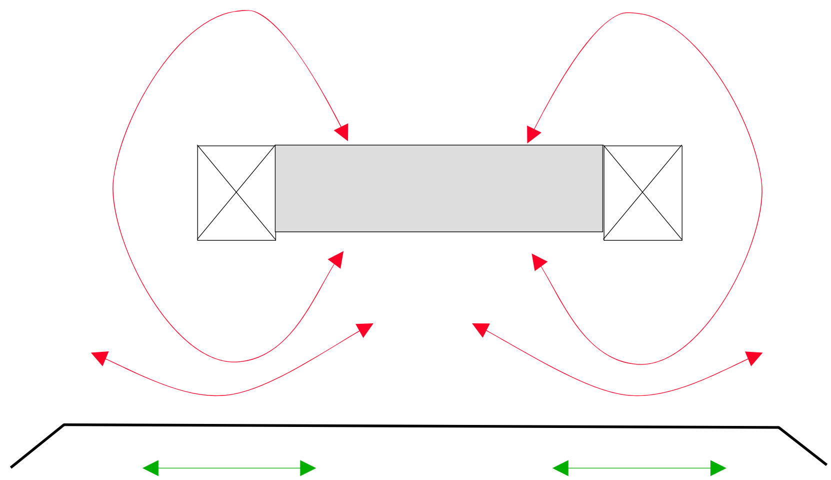

Figure 1-4 Principle of inductive distance measurement

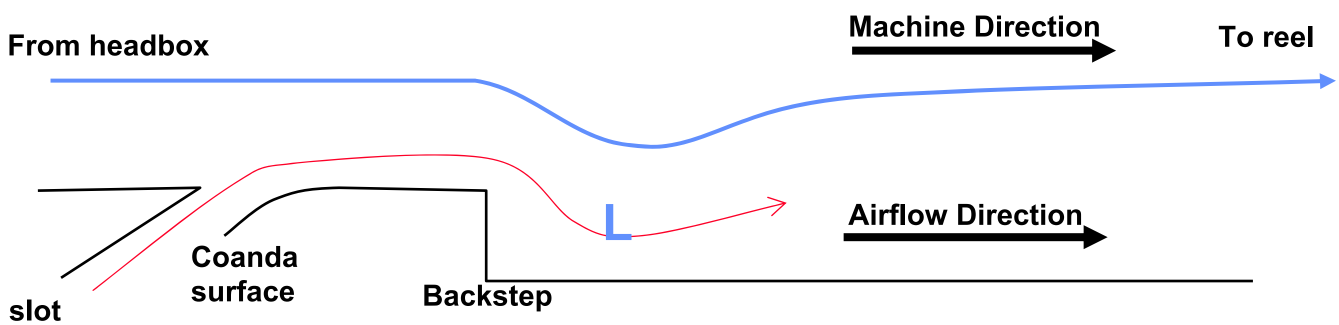

Figure 1-5 Principle of air clamp operation

Figure 1-5 is a diagram of the Coanda air clamp. High velocity air is directed from a plenum around the curved Coanda surface. This creates a high velocity flow parallel to the sheet. The flow is allowed to expand by going over a back step that creates a stable low pressure region. The sheet is pulled into this region and forms a minimum position over the measurement position. This air clamp stabilizes the sheet such that it is always within the measurement range of the lasers. There is enough air injected under the sheet that it is prevented from coming in contact with the dome downstream of the air clamp.

The minimum position created by the air clamp is extremely important for the measurement. Any angle will lead to measurement error since the scanner heads cannot be perfectly aligned throughout the scan: there is an inevitable xy wander.

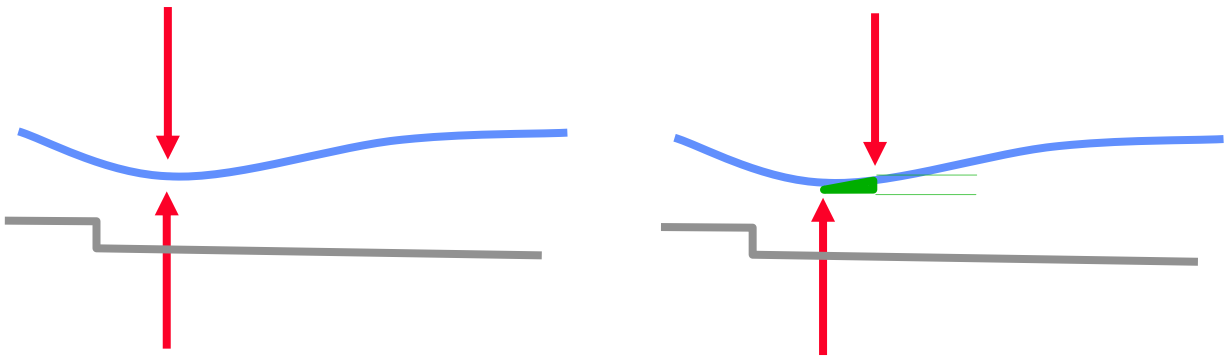

Figure 1-6 Laser misalignment leads to measurement error

1.3.2. Calibration module

The calibration module is so called because it includes a moveable target that is used for calibration. Figure 1-7 Figure 1-8, and Figure 1-9 identify the major components of the calibration module. Assembly drawings are included in Chapter 9.

Basic features of the calibration module include:

- An optical triangulation device that reports an output voltage from which the distance of the sheet from the calibration-module laser can be inferred through its calibration relationship. The aluminum structure of the optical triangulation unit is temperature controlled with a resistive heater adhered to its side. The temperature of the aluminum case is monitored by a thermistor embedded into the aluminum casing. Electronics on the calibration module PCBA provide active feedback to hold the laser case at approximately 43°C.

- The stainless steel target is the part of the module that emerges through the scanner hole and faces the sheet. It is six inches in diameter. The target can be raised or lowered, towards or away from the sheet by an on-board stepper motor and sliding table arrangement. There are two purposes for the target's movement. The first is to enable online calibration, that is, moving a flag through the range of the direct devices and re-establishing their voltage to displacement relationships. The second is the moveable dome allows flexibility in selecting the dome position for optimum measurement. The dome does not move during regular onsheet measurement operation.

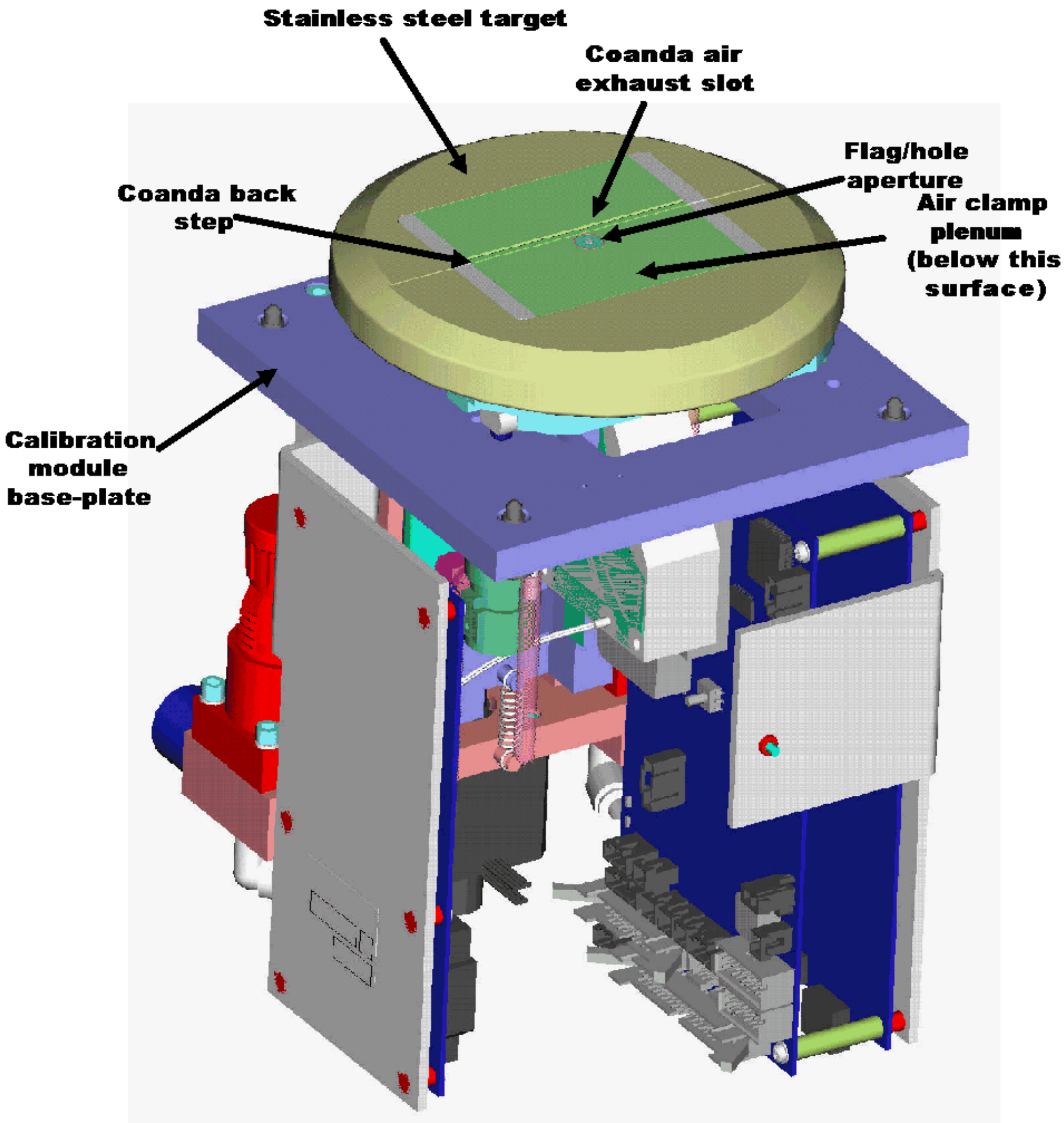

Figure 1-7 Calibration module part detail (1/3)

- The Coanda air clamp is the narrow slot that is seen on top of the stainless steel target. It provides a high flow of air, parallel to the sheet, to hold the moving sheet in a flat position desirable for measurement. The air to the air clamp can be manually adjusted through a mini-regulator. An input tube from the scanner manifold attaches to the mini-regulator input and a length of tubing connects the mini-regulator outlet to the plenum inlet fitting. The flow rate through the system can be identified by reading the analog pressure meter attached to the mini-regulator. The pressure in the air clamp plenum is measured electrically by connecting a length of tubing from a plenum fitting to a PCBA mounted pressure gauge. This plenum pressure signal is available on the Da Vinci system. See Figure 1-8 for the underside detail of the air clamp, including the identification of air-provisioning hoses.

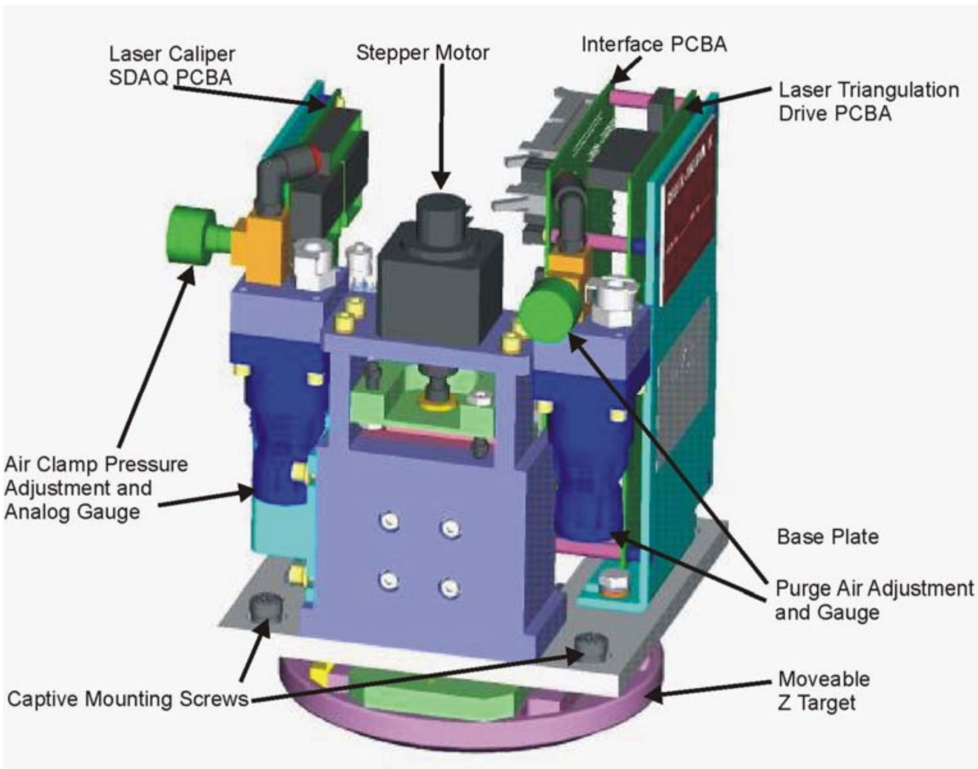

Figure 1-8 Calibration module part detail (2/3)

- The LVDT is present in the calibration module. The LVDT tracks the vertical displacement of the dome. The LVDT provides a voltage signal that is interpreted as a displacement by Da Vinci. Unlike the direct devices, the LVDT calibration LUT cannot be renewed online (there is little reason to do this). The LVDT calibration relationship is derived in the Honeywell factory and is included as a computer file with shipment of the sensor. There are three purposes of the LVDT. The first is the LVDT acts as a displacement standard during calibration. As the target carries the flag through the calibration range of the direct devices, the LVDT reports the target displacement at every point. Using the displacement array from the LVDT and the signal arrays collected from the direct devices, Da Vinci is able to build the calibration relationships for the direct devices. The second is the LVDT monitors the distance between the triangulation device and the dome which can change slightly due to thermal or mechanical effects. The third is to accurately position the dome while scanning or while standardizing.

- The flag-toggling mechanism is included in the calibration module. The flag-toggling mechanism can be in one of two states: open or closed. When open, a purged hole is present and the calibration module's laser can see the sheet. When in place, the flag provides an optical target for both calibration module and z-module simultaneously. The flag provides an absolute caliper sample at standardize and because it is seen by both optical triangulation devices, it allows both optical triangulation devices to be calibrated simultaneously during the same dome movement. Physically the flag is driven by an electrically controlled pneumatic solenoid.

- There are a total of three PCBA cards included in the calibration module: the calibration module interface PCBA, the optical triangulation controller card, and the laser caliper SDAQ card. The calibration module interface PCBA (6581500002) is the common interface for all sub-devices and other PCBs in the module. Da Vinci's point of contact with the calibration module is with the interface PCBA.

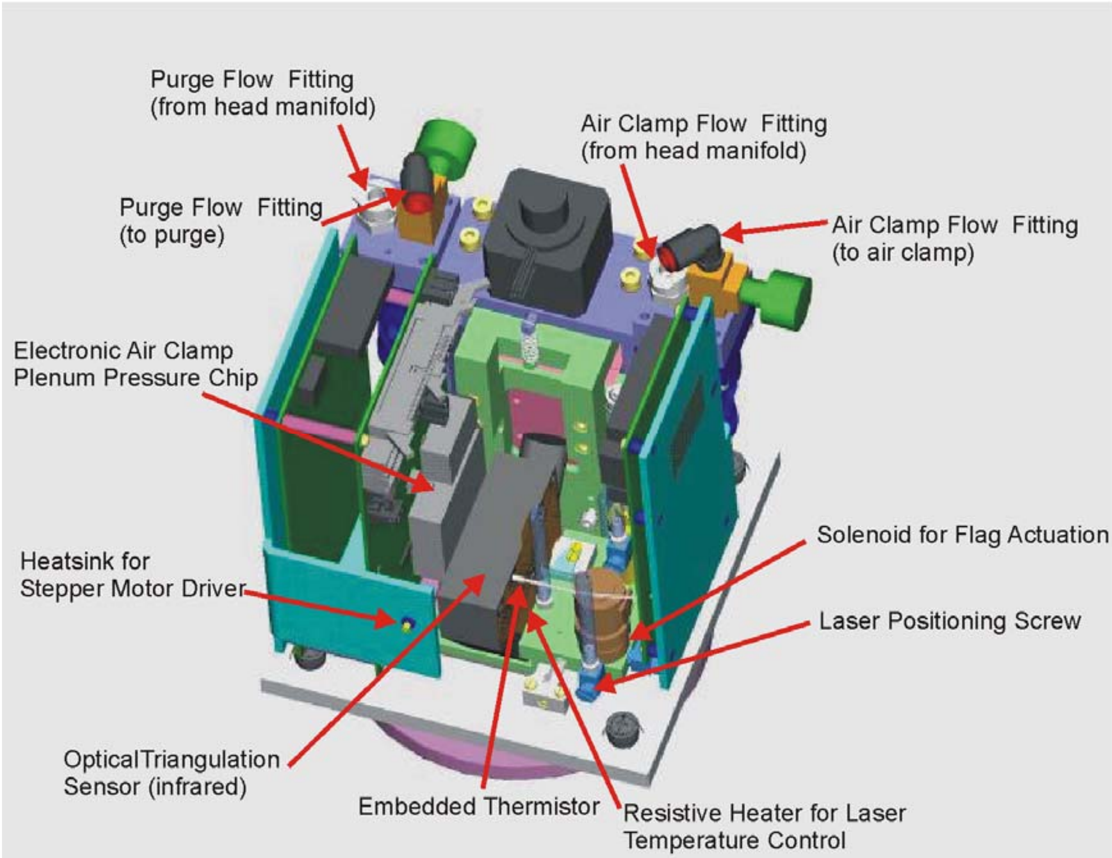

Figure 1-9 Calibration module part detail (3/3)

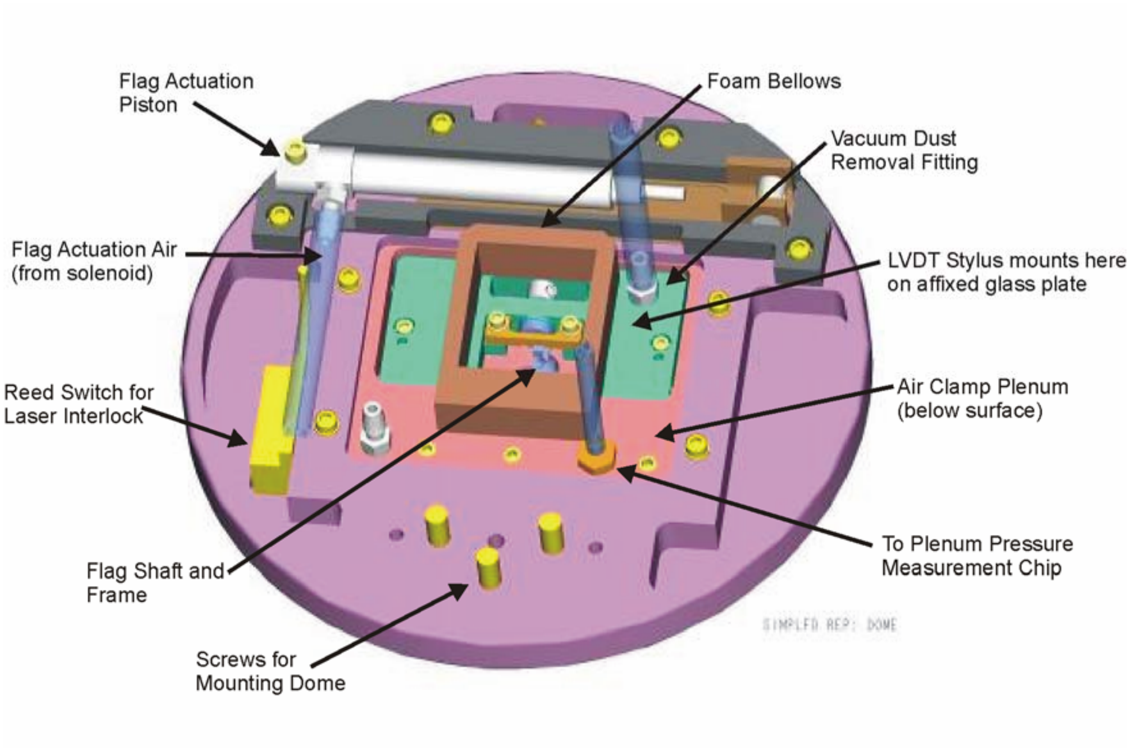

Figure 1-10 Calibration module part identification

- Due to the detrimental influence of dust on an optical imaging measurement, the calibration module has an air purge. A keyhole plate is placed in front of the laser. Air is exhausted underneath this plate. It then flows through the three-mm wide slot (see Figure 1-9). The uni-directional flow prevents dust from settling on the optics. The purge flow is manually adjustable from an on-board mini-regulator. The keyhole plate can be removed when cleaning is necessary. The calibration module (and scanner head) is sealed by a flexible foam bellows that encircles the optical path of the viewing optics, see Figure 1-8. In order to access the keyhole plate, the dome is attached to its bracket with three screws with are accessible from outside the scanner heads. These can be removed and the dome can be pulled away from the sensor.

- Figure 1-11 shows how the calibration module triangulation laser and the LVDT are mounted on a common bracket. The LVDT emerges through a spring loaded stylus. The reason for this mechanical arrangement is that, in addition to intended dome translations through the stepper motor, the LVDT can also report more subtle thermal breathing between the underside of the done and the bracket. Directly measuring this distance enables the LVDT correction that helps reduce absolute caliper errors due to thermal changes.

- Since the stainless steel dome is electrically conductive steps have been taken to electrically isolate the sensor from the sheet. The bracket to which the dome mounts is made from glass-filled nylon and the LVDT stylus presses on a glass plate epoxied to the underside of the dome.

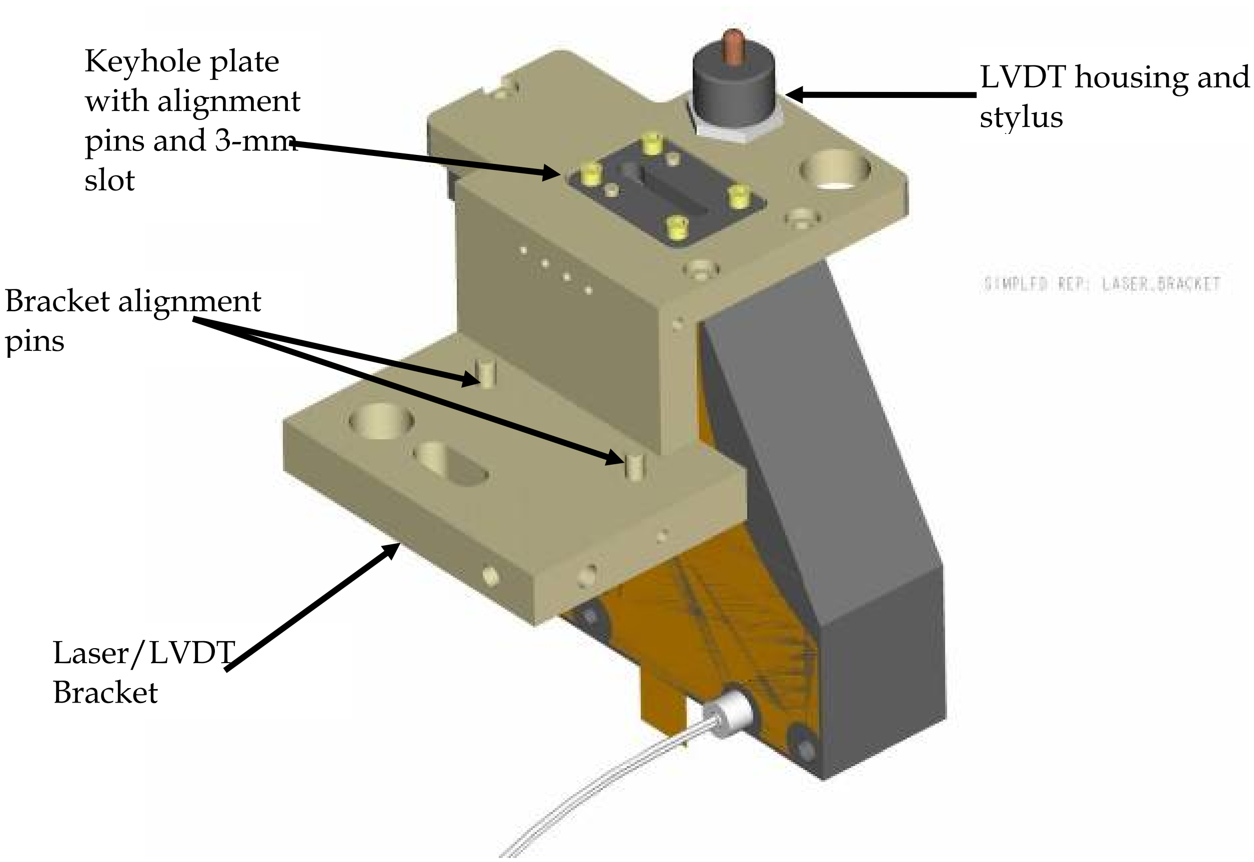

Figure 1-11 Calibration-module triangulation laser and LVDT mounted on translation bracket

1.3.2.1. Calibration-module electronics

The only electrical connection between the scanner and the cal-module sensor is through the cal-module interface PCBA (6581500002). Specifically, it provides power, sends analog signals to, and receives digital signals from the SDAQ (6581500013) and it provides power to and receives analog signals from the laser control board (6581500029). A layout drawing of the front of the interface board is shown in Figure 1-12. For troubleshooting purposes there are test points and LEDs on the card to which clip type DMM probes can be attached. These LEDs and test points can be identified with Table 1-1. More details of the card can be determined through the electrical layout drawings: Figure 9-6 and Figure 9-7. With the current version of the sensor, all signals are transmitted through the power track digitally. The laser caliper uses a modified version of the SDAQ (6581500013). The stepper motor pulses are generated by the SDAQ and special firmware is necessary to do so.

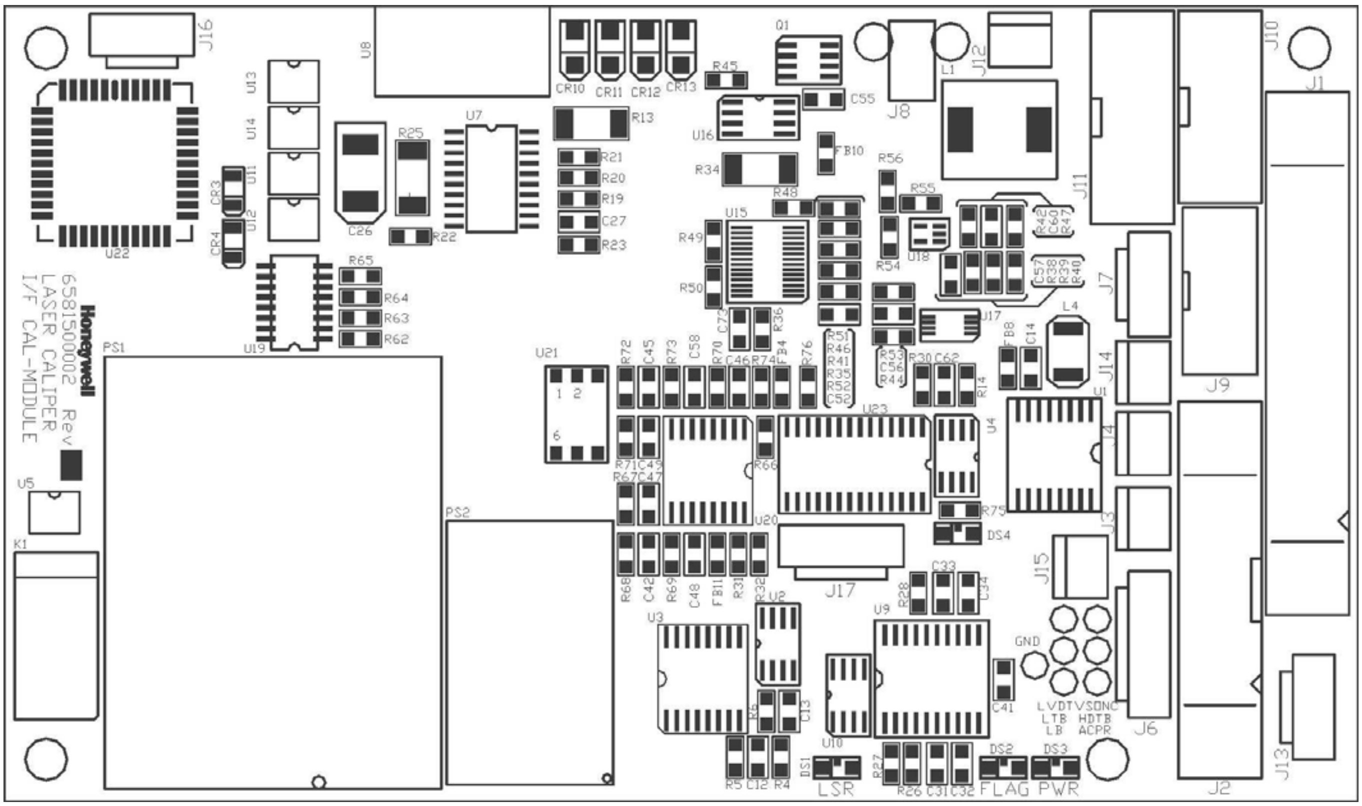

Figure 1-12 Layout of calibration-module PCBA (6581500002). The test points and LEDs are in the lower right hand quarter

Table 1-1 Calibration-module PCBA electrical test point and LED identification

PCBA screen print label	Signal indication	Expected signal for properly functioning sensor
GND	Ground	-
LVDT	LVDT displacement	-10 to 10 V should move when dome moves

PCBA screen print label	Signal indication	Expected signal for properly functioning sensor
LTB	Cal-module laser case temperature	1.22 to 1.26 V
LB	Cal-module laser displacement	-10 to 10 V should move when dome moves
VSONC	Not used	-
HDTB	PCBA temperature	0.95 to 1.2 V
ACPR	Air clamp plenum pressure	1 to 3 V
LSR	Laser power LED –expect emission if on	ON
FLAG	Flag status LED	ON if flag retracted
PWR	Board power LED	ON

1.3.3. Z-sensor module

The z-sensor module (or z-module) has its name because it includes the inductive proximity sensor—the so-called z-sensor. The basic features of the z-sensor module are listed in this section.

- Similar to the calibration module, the z-sensor module includes an optical triangulation device that reports an output voltage from which the distance of the sheet from the calibration module laser can be inferred through the calibration relationship. The aluminum structure of the optical triangulation unit is temperature controlled by a resistive heater adhered to its side. The temperature of the aluminum case is monitored by a thermistor embedded into the aluminum casing. Electronics on the z-sensor module PCBA board provide active feedback to hold the laser case at approximately 43°C.

- As with the calibration module, there are also three PCBA cards in the z-sensor module: the z-sensor module interface PCBA, the optical triangulation controller card, and the laser caliper SDAQ card. The calibration module interface PCBA (6581500001) is the common interface for all sub-devices and other PCBs in the module. Da Vinci's point of contact with the z-sensor module is with the interface PCBA.

- Due to alignment requirements, the z-module is built so that an inner translation plate can be moved in two dimensions relative to base plate. This translation is done through the alignment stages. Figure 1-13 shows the detail of the components mounted on the translation plate. To perform alignment operations, it is important to understand that these pieces move as a rigid unit relative to the base plate. The base plate is in turn fixed to the scanner platform.

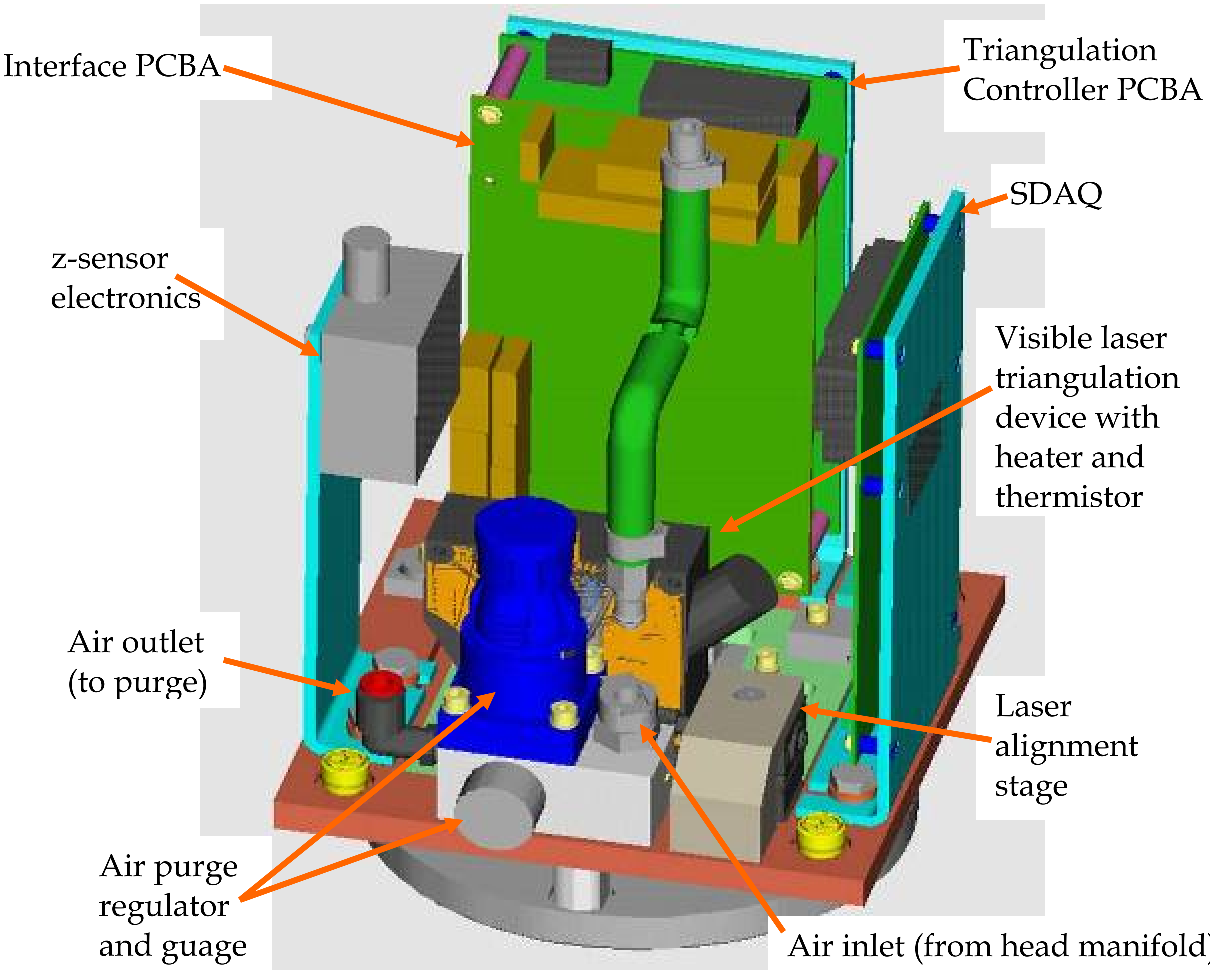

Figure 1-13 Z-sensor module part detail (1/2)

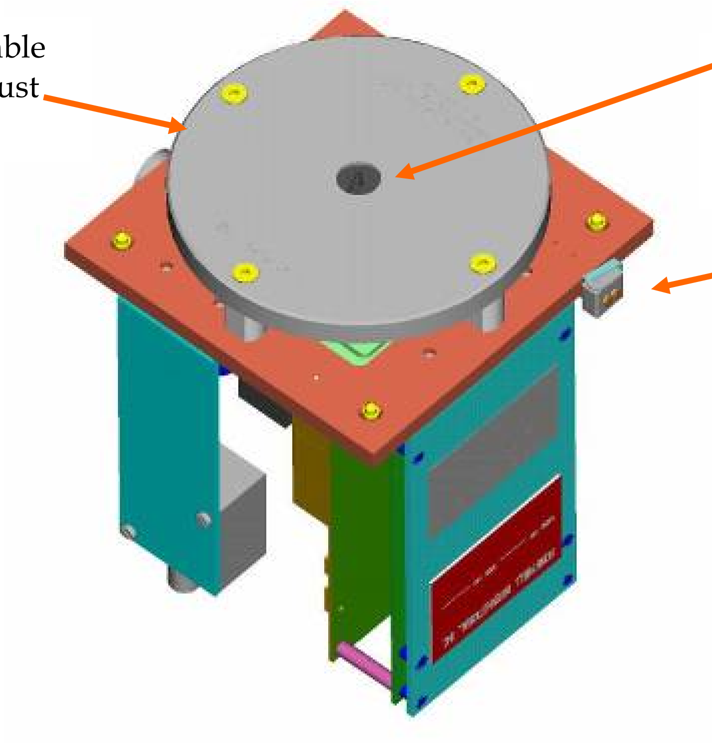

Figure 1-14 Z-sensor module part detail (2/2)

- The inductive proximity sensor determines the head separation of the modules, and provides the *Z(x)* term required to express the measurement of Equation 1-1. The z-sensor consists of controlling electronics and a ceramic coil form around which the wire wraps are affixed. The controlling electronics are shown in Figure 1-12 and the coil itself is best seen in the detail of Figure 1-15. The z-sensor coil form is mechanically attached to the z-module optical triangulation unit so that there can be no relative movement between the two devices. The z-sensor coil-form is temperature controlled by two thermo-electric coolers (TEC).

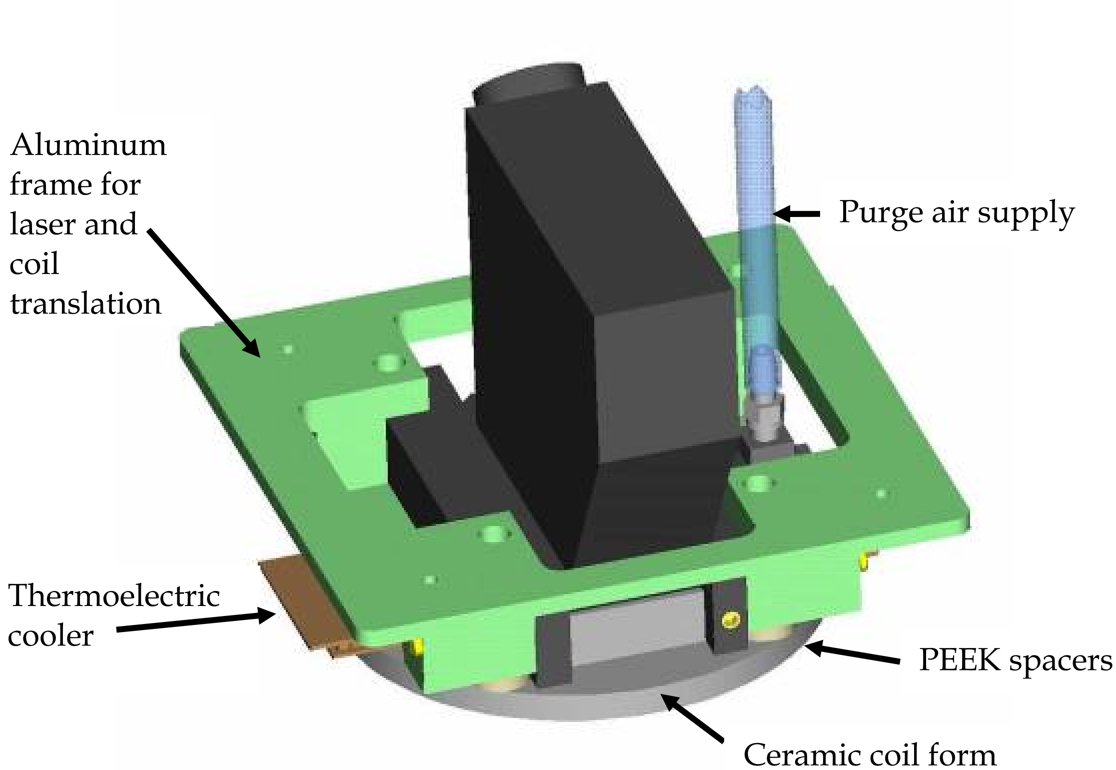

Figure 1-15 Z-sensor triangulation device and z-sensor coil form attached to aluminum translation plate

- For dust resistance, the z-module includes a purge function intended to keep the optical path free of dust buildup. Figure 1-16 shows the details of the purge arrangement. A tube provides flow to a purge chamber that is formed below a keyhole insert. The mechanics that form the purge chamber mount around the base of the optical triangulation unit and slide concentrically into the z-coil form. The keyhole insert can be removed to clean the triangulation optics.

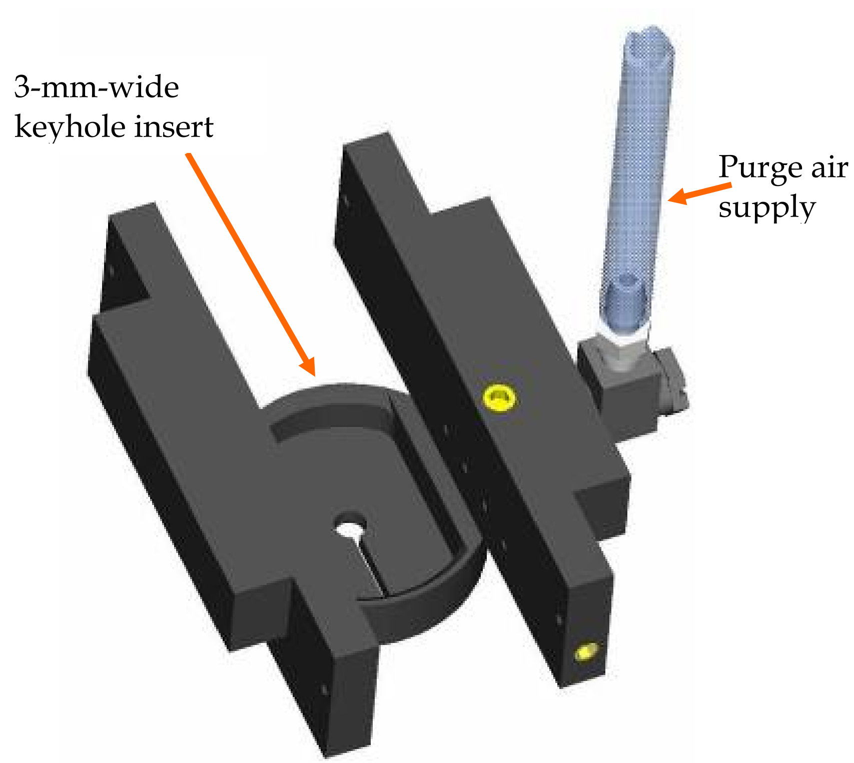

Figure 1-16 Z-sensor module purge arrangement. The laser fits between the two side pieces and over the circular coil-form insert

1.3.3.1. Z-module electronics

The only electrical connection between the scanner and the laser caliper sensor is through the z-module interface PCBA (6581500001). The interface provides power. It also sends analog signals to, and receives digital signals from, the SDAQ (6581500013).In addition, it provides power to and receives analog signals from the laser control board (6581500029). A layout drawing of the front of the interface board is shown in Figure 1-17. For troubleshooting purposes there are test points on the card to which clip-type DMM probes can be attached. These test points can be identified with Table 1-2. More details of the card can be determined through the electrical layout drawings: Figure 9-6 and Figure 9-7. With the current version of the sensor, all signals are transmitted through the power track digitally.

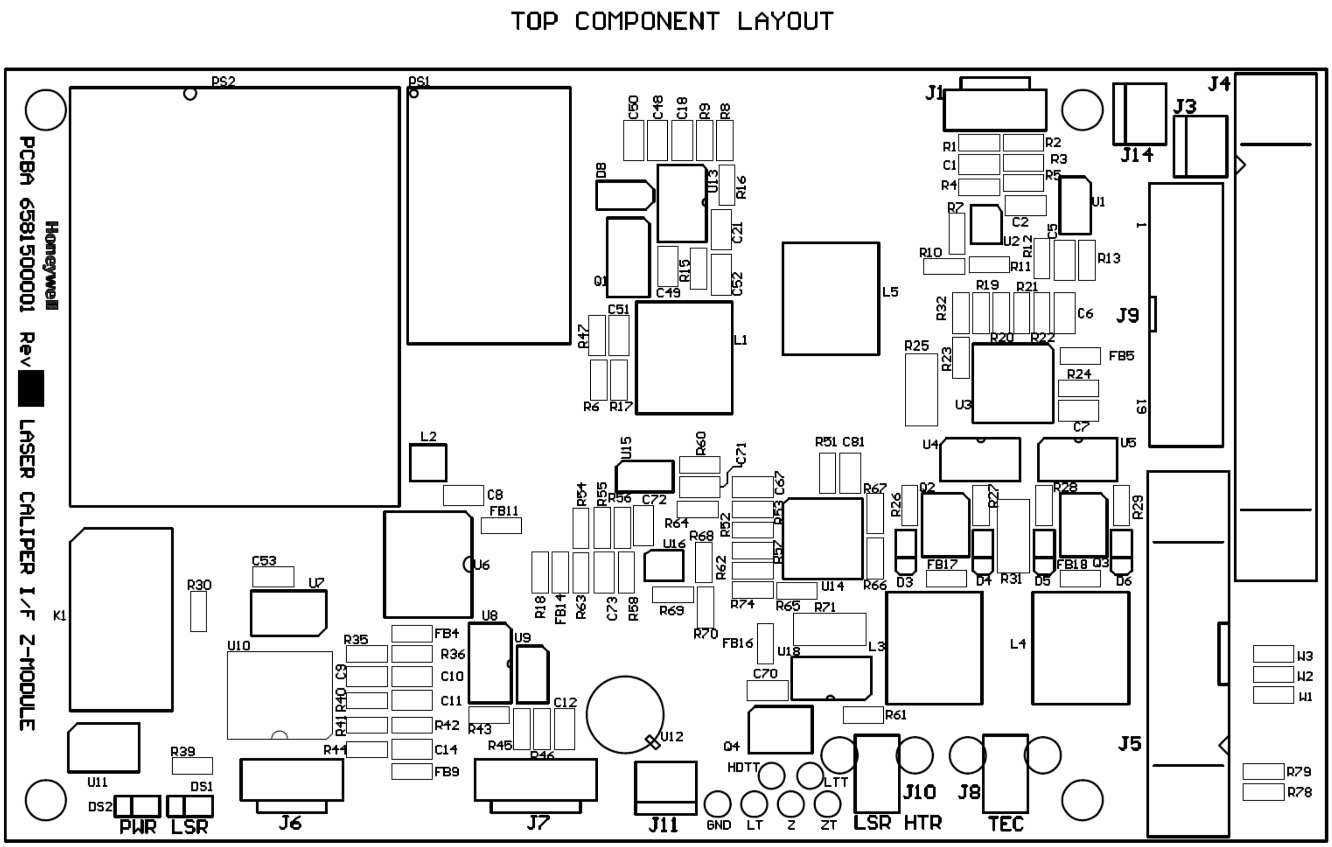

Figure 1-17 Layout of z-module interface PCBA (6581500001). The test points are in the middle of the bottom edge

Table 1-2 z-module interface PCBA (6581500001) electrical test point and LED identification

PCBA screen print label	Signal name	Expected signal for properly functioning sensor
GND	Ground	-
HDTT	Head temperature	0.95 to 1.2 V
LTT	Laser temperature	1.22 to 1.26 V
LT	Z-module laser displacement	-10 to 10 V should change when dome moves and flag inserted.
Z	Z-sensor signal	-6 to 3 V should change when dome moves.
ZT	Z-sensor temperature	1.5 to 1.7 V
LSR	Laser power LED –expect emission if on	ON
PWR	Board power LED	ON

1.3.4. Alignment tool hardware description

The alignment tool is a peripheral device shipped with the NCC that aligns the laser beams mutually on the same spot of the sheet. Figure 1-18 is a schematic of the alignment tool.

The device is to be temporarily installed during commissioning by inserting the tongue into the scanner gap and attaching to the scanner mount bracket to the lower head scanner sheet guide. The optical position sensitive detectors, present on both upper and lower sides of the tongue, provide sensing targets for the two laser beams from the two triangulations sensors of the calibration and z-modules.

A panel display indicates the absolute or relative offsets of the upper/lower laser alignment. A detailed description of how to perform an alignment operation is described in Subsection 3.2.6.

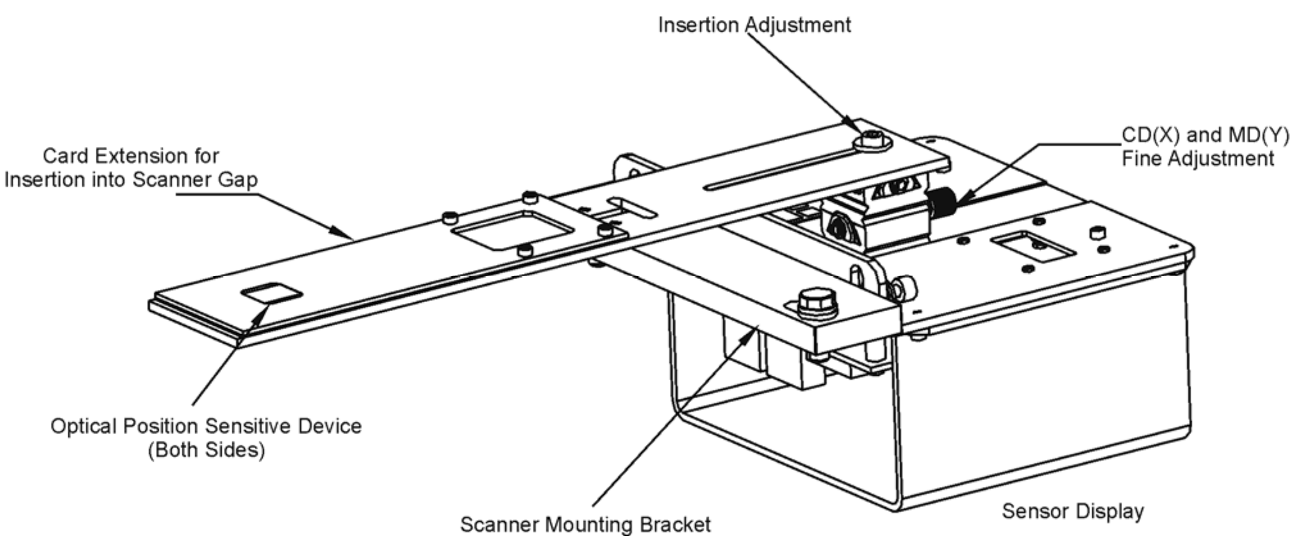

Figure 1-18 Alignment tool part identification

1.4. Da Vinci signal family description

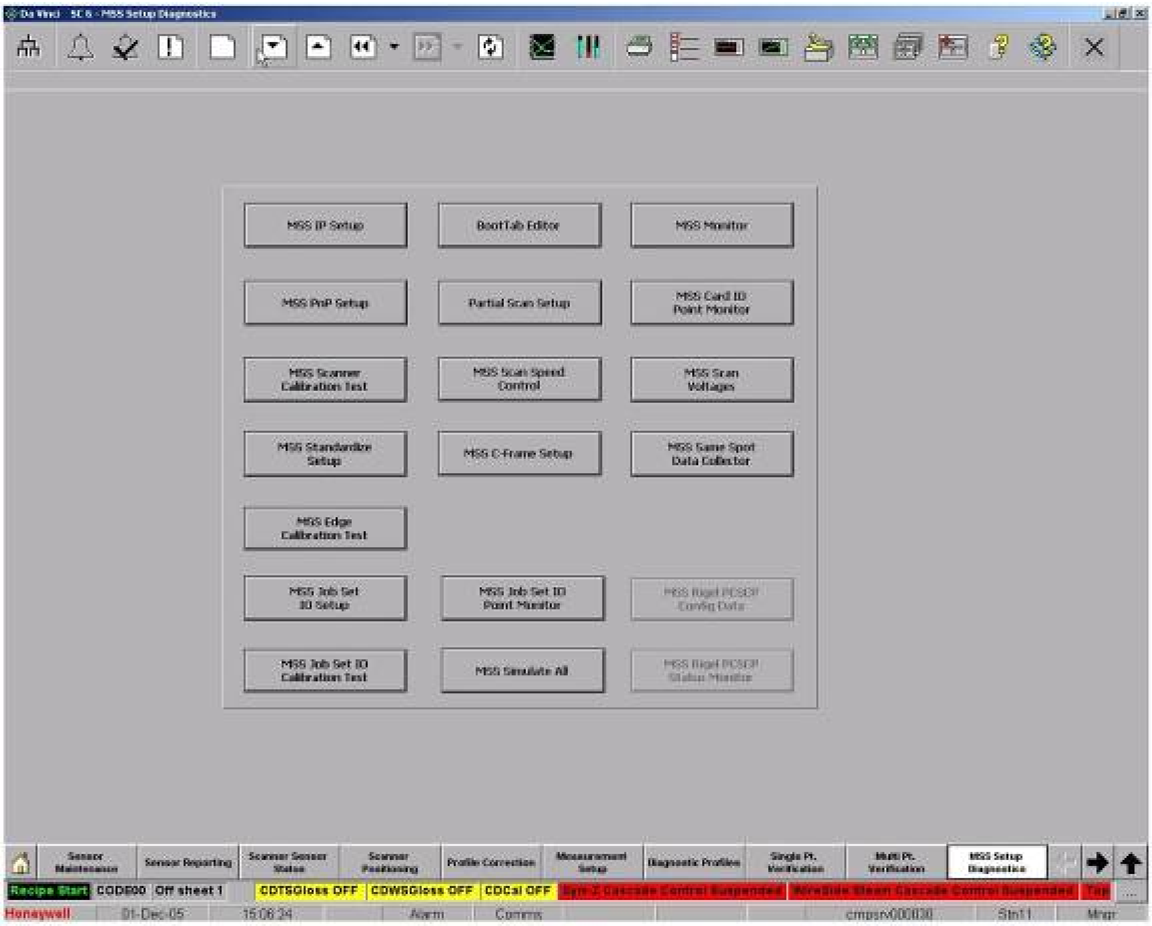

Figure 1-19 MSS Setup Diagnostics

The family of signals from the NCC from the MSS can all be viewed from the Da Vinci terminal through the **MSS Setup Diagnostics** display, seen in Figure 1-19. Select the **MSS Job Set IO Point Monitor** button and a new display appears, see Figure 1-20. For commissioning and troubleshooting, confirm the raw signal voltages are reasonable before attempting to interpret the measurements in engineering units.

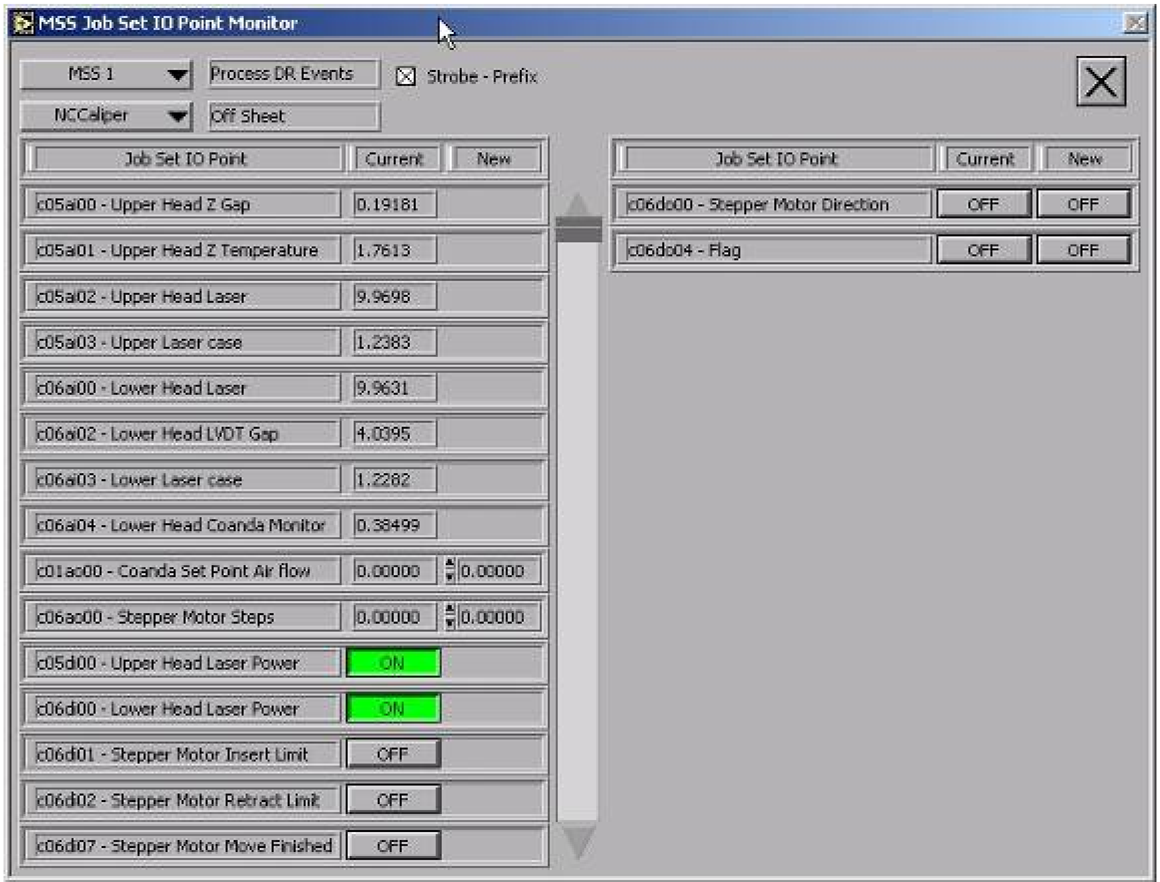

Figure 1-20 MSS Job Set IO Point Monitor

From this simple menu, significant information can be gleaned about the functional health of the NCC gauge.

i **NOTE:** Originally the gauge was intended to have only one configuration, that is, the calibration module was intended to be installed only in the lower scanner head. This is no longer the case. The calibration module can be installed in the upper or lower head as the environment dictates. The Da Vinci signal names do not yet reflect this change. Everywhere **Upper head** appears on a Da Vinci display, interpret this as z-sensor module and everywhere **Lower head** appears, interpret this as calibration module.

Table 1-3 NCC signal complement

Signal name	Comment
Upper head z-gap [V]	Signal representing the displacement measured by the z-module's z-sensor. Signal maps a ±1500 μm displacement range into approximately a -6V to +2V signal range. Signal reads more negative when its target (the stainless steel dome) moves closer to the z-module.
Upper head z-temperature	Signal representing the temperature of the temperature controlled z-coil. The relationship to convert between signal, V_{ZT}, in volts, and temperature, T_{ZT}, in ^{o}C, is: $T_{ZT} = 8.4285\ V_{ZT}^{2} – 58.484\ V_{ZT} + 117.15$
Upper head laser	Signal representing the displacement measured by the z-sensor module optical displacement device. Signal maps a ±1500 μm displacement range into ±10 V signal range. Signal reads more negative when its target (flag or sheet of paper) moves closer to the z-sensor module.
Upper head laser case	Signal representing the temperature of the temperature controlled z-sensor module optical triangulation unit's aluminum housing. The relationship to convert between signal, V_{UH}, in volts, and temperature, T_{UH}, in ^{o}C, is: $T_{UH} = 12.506\ V_{UH}^{2} – 76.21\ V_{UH} + 117.6$
Lower head laser	Signal representing the displacement measured by the calibration module optical displacement device. Signal maps a ±1500 μm displacement range into ±10 V signal range. Signal reads more negative when its target (flag or sheet of paper) moves closer to the calibration module.
Lower head LVDT gap	Signal representing the displacement measured by the calibration module LVDT. Signal maps a ±1700 μm displacement range into ±10 V signal range. Signal will read more negative when its target (lower stainless steel) moves further into the gap.
Lower laser case	Signal representing the temperature of the temperature controlled calibration module optical triangulation unit's aluminum housing. The relationship to convert between signal, VUH, in volts, and temperature, T_{UH}, in ^{o}C, is: $T_{UH} = 12.506\ V_{UH}^{2} – 76.21\ V_{UH} + 117.6$
Lower head Coanda monitor	Signal representing the plenum pressure inside the calibration head, immediately before the flow emerges from the air clamp. The relationship to convert between signal, V_{CM}, in volts and pressure, P_{CM}, in psi, is: $P_{CM}=32.24\ V_{CM} - 6.5$
Coanda set point air flow	This parameter is not used.

Signal name	Comment
Stepper motor steps	This field can be used to command stepper motor steps directly to the MSS. The calibration module target displacement is related to the number of steps by the following ratio: 0.656 steps per micron. An entry of **0** steps must be entered between subsequent moves while using this display in order to reset the **Stepper motor move finished flag**.
Upper head laser power	This digital input indicates the state of the z-sensor module laser power. This indicator is ON if the system interlock is satisfied.
Lower head laser power	This digital input indicates the state of the calibration module laser power. This indicator is ON if the system interlock is satisfied.
Stepper motor insert limit	This digital input indicates whether the calibration module's dome is at the extreme insertion limit of its travel.
Stepper motor retract limit	This digital input indicates whether the calibration module's dome is at the extreme retracted limit of its travel. Also called the *home* position.
Stepper motor move finished	This digital input indicates that the stepper motor has completed executing a requested move. If on, it must be reset before subsequent moves can be made (see entry for **Stepper motor steps**).
Stepper motor direction	This digital input indicates the requested motion direction of the calibration module's target (dome). The **OFF** status indicates the dome will move towards the full retract position, and an **ON** indication means the dome will travel into the gap towards its insert limit.
Flag	This digital input indicates the presence or absence of the opaque flag in the calibration module's dome. The **ON** status corresponds with the flag being present in the lower dome, **OFF** indicates it is retracted out of the beam path.
Coanda Pressure Step	Not used
Coanda Pressure Direction	Not used

1.5. Safety notes and interlock description

1.5.1. Gauge radiation certification and safety notes

When the laser caliper is integrated into a 4000 series scanner, it is classified as a Class I device (cannot emit laser radiation at known hazard levels). Power the device only when it is properly integrated into the scanner, as the scanner acts as an enclosure for the embedded red and IR laser devices which, if powered outside the scanner, would be classified as IIIa and IIIb respectively. Class IIIa lasers are only hazardous for intrabeam viewing (directly into eye). Class IIIb lasers are slightly more hazardous. In this case the increased hazard arises because the laser is invisible. For a visible beam the eye limits its exposure through a blink response. This response does not exist for an infrared beam.

The scanner enclosure includes an interlock that extinguishes laser emission for conditions where it would be otherwise possible to view the beams. The class I designation relies on this interlock.

WARNING! Do not attempt to defeat or otherwise tamper with the interlock system.

1.5.2. Laser interlock

The function of the interlock is to prevent human exposure to laser radiation at unsafe levels. Each of the laser devices require that current flows through a relay to pull an enable pin to ground. If the laser is not enabled, there is no emission. See Figure 1-21 for a generalized schematic of the interlock which is true no matter which module is in which scanner head. The principle of the interlock is: if any of the following actions occur, both lasers are extinguished simultaneously:

- the heads are split,
- the z-module is lifted from the scanner platform, (it is impossible to remove the laser device without removing the module),
- the calibration module is lifted out off the scanner platform,
- the laser keyswitch is turned off, or
- the cal-module laser is removed from its bracket.

The active components in the interlock circuit are the keyswitch, a reed switch mounted in the calibration module coupled with a magnet mounted in the z-module dust cover, and in-place switches in each module.

The active element of the reed switch is attached in the calibration module's stainless steel dome and is connected to the calibration module's PCBA (6581500002-J14). In the z-module, a magnet is embedded in the PEEK dome that, when sufficiently close to the stainless steel calibration module dome, will close the reed switch and allow current to flow through the interlock. It is extremely unlikely that this reed switch will fail in the closed position, considering the switch is actually comprised of two switches in series and each of these switches has an expected lifetime of 5M cycles. In the expected lifetime of any sensor the switches are expected to be toggled only a small fraction of this number.

A keyswitch will be installed on all new systems and is recommended as a retrofit on all systems in which a NCC is to be installed. If the configuration card set is a lower level than G, then a modification to the endbell configuration card in the 4000 scanner is necessary.

The specifics of the interlock including the routing between the upper and lower scanner head and to the keyswitch is shown in Figure 1-22 for a system with a config F board set and the calibration module in the lower head, Figure 1-23 for a config F board set with the calibration module in the upper head, and Figure 1-24 for a config G board set with the calibration module in the upper head. With a config G board set, the diagram is essentially the same for both orientations. There is only one cable between the config G board and each module independent of the orientation. The only change is a software change.

Safe procedures for servicing the laser caliper sensor are described in Section 6.1.

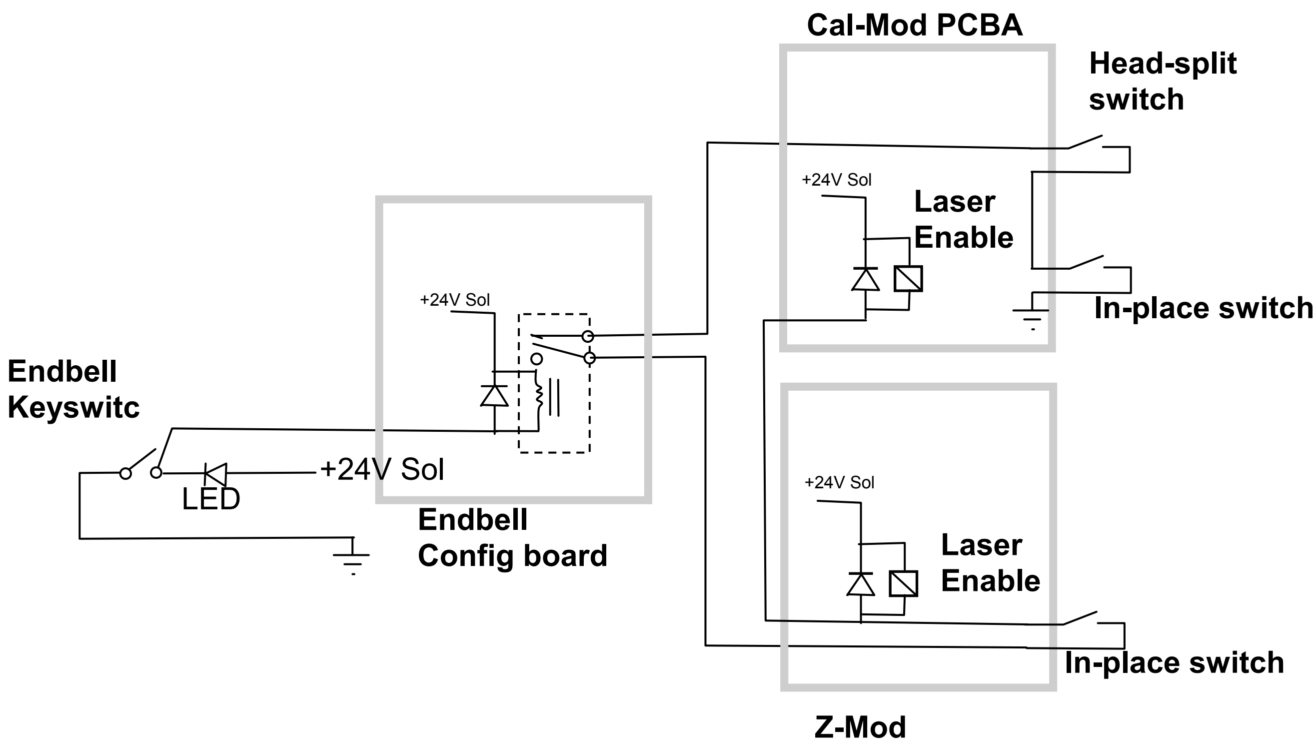

Figure 1-21 Generalized interlock schematic

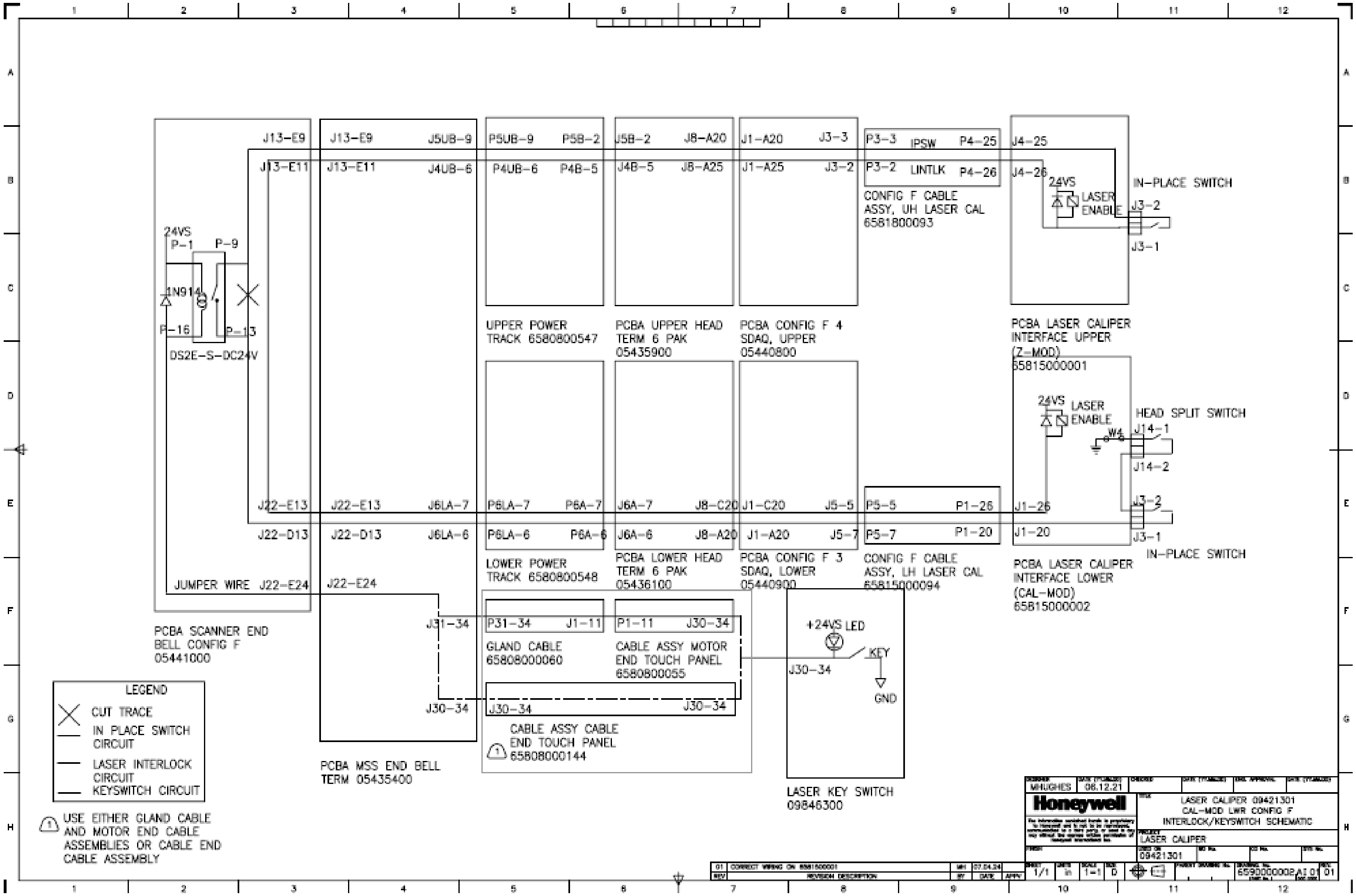

Figure 1-22 Interlock schematic for configuration with z-module in upper head and calibration module in the lower head

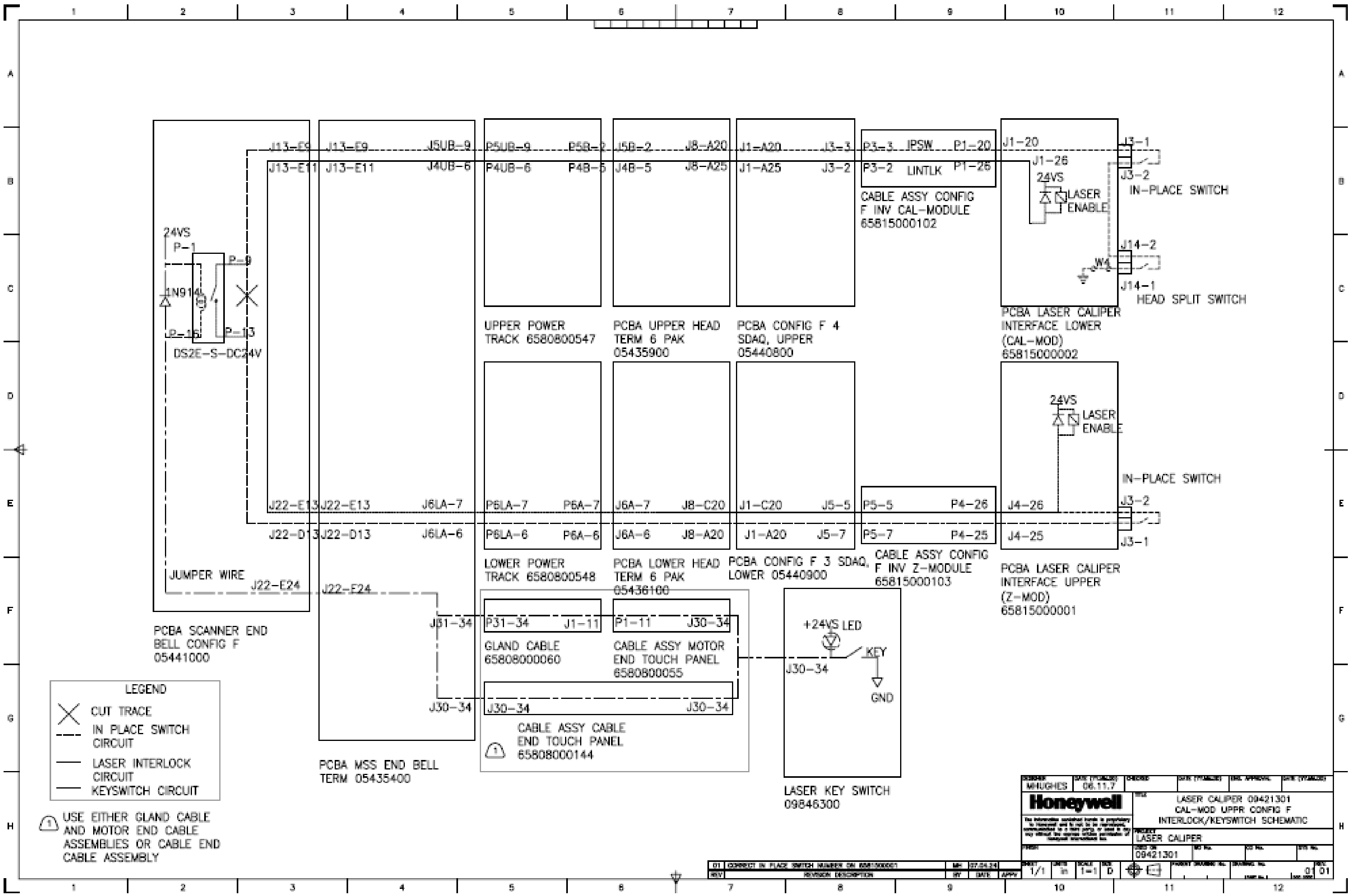

Figure 1-23 Interlock schematic for calibration module in upper head and z-module in lower head

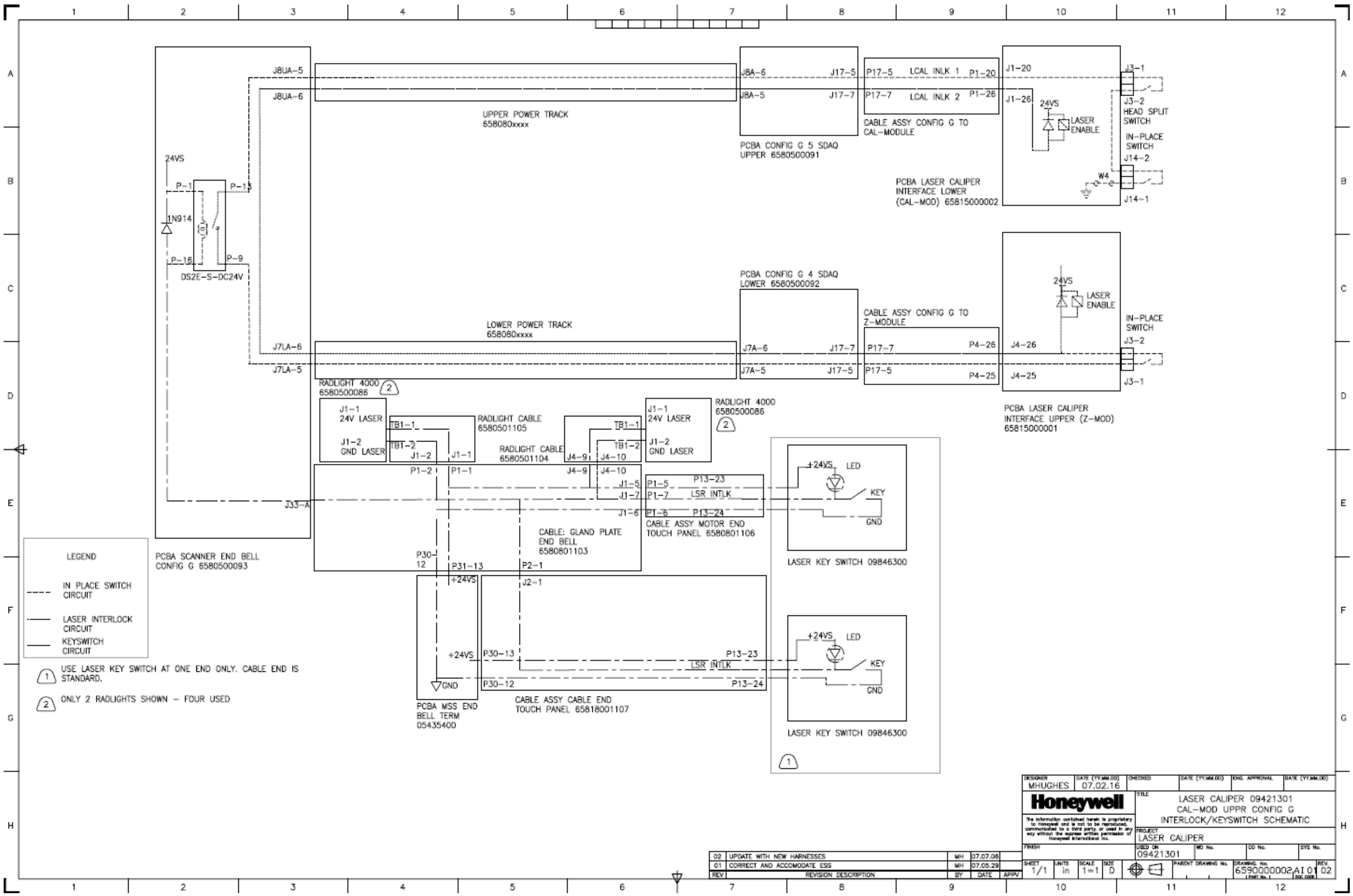

Figure 1-24 Interlock schematic for config G board set

2. Gauge Functional Basics

2.1. Measurement range

The NCC gauge is designed to be integrated on 4000-type scanners that have a 10-mm (0.4-in) gap between the sheet guides. Because the non-contacting measurement is a combination of relative displacements, the set up of the scanner influences what is called the *measurement overlap range*. See Figure 2-1. The sheet guide gap is nominally 10 mm (0.4 in) wide. The direct measurement devices in the non-contacting gauge are tuned so that they all have a 3-mm (0.118-in) measurement range. The devices give a signal that has meaning when converted into displacement, surrounded by 4-mm (0.157-in) deadband on either side the top or bottom of the gap. If a device's target is sitting outside its measurement range, the device will report a misleading reading. For example, if the sheet sits in the top 4-mm (0.157-in) of that gap, expect one optical triangulation device to read on the 10-V rail and the other on the -10-V rail.

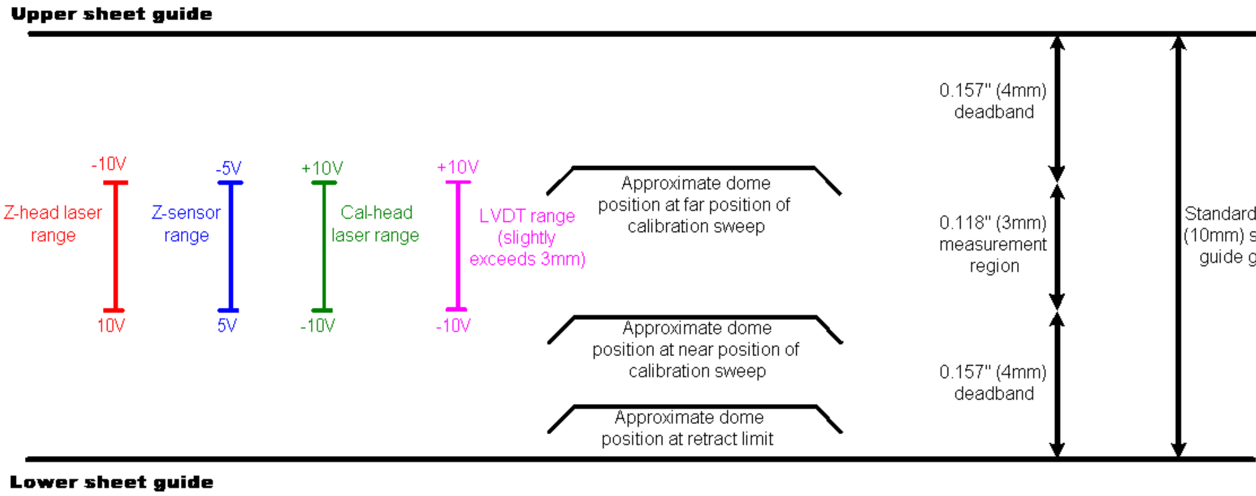

Figure 2-1 Measurement overlap range, deadbands and typical dome positions

If the scanner head gap is not to specification, it will suffer in measurement overlap range. See Figure 2-2. A scanner with a non-ideal gap reduces the overlap range in which a measurement can be made. This reduction can be accommodated by positioning the air clamp relative to the remaining overlap range, but remember that there are consequences to a non-ideal sheet gap.

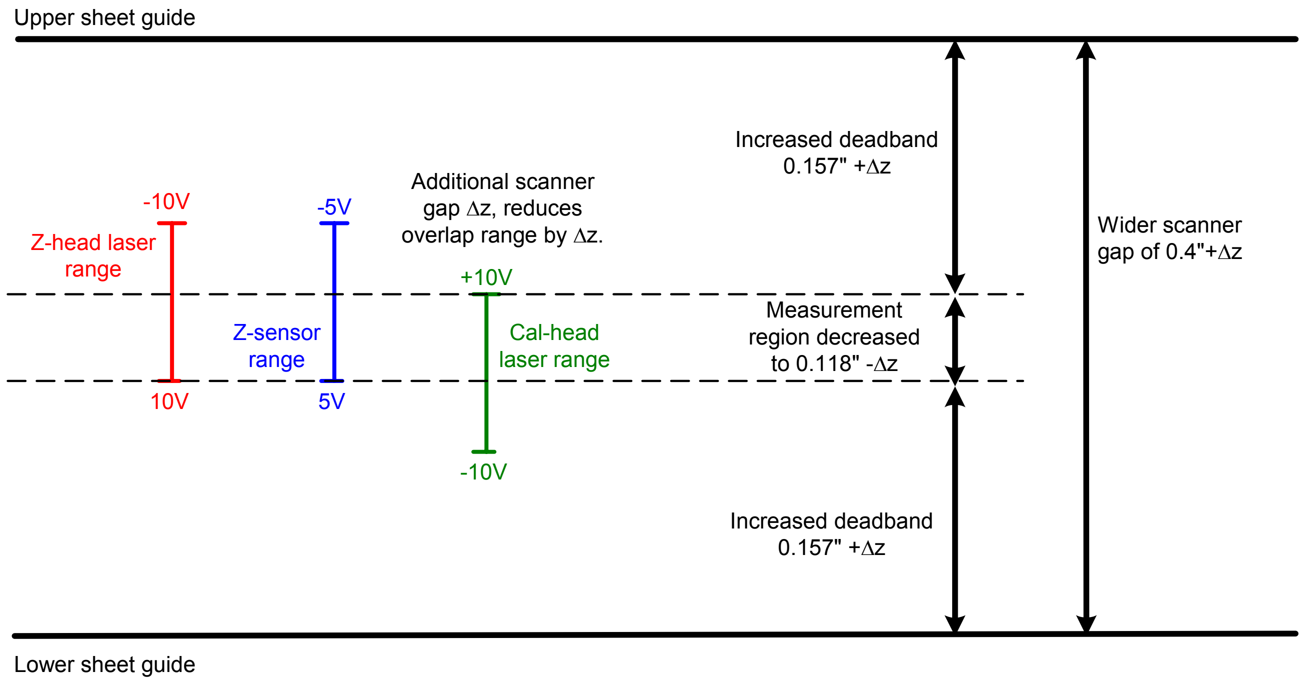

Figure 2-2 Overlap range as influenced by scanner sheet gap

For a caliper measurement to be possible the sheet must simultaneously be in range of each laser and the stainless steel dome must be in range of the z-sensor. As well, the entire range of the each device must be available for calibration. The latter point is generally satisfied as the LVDT has slightly more than 0.118 in of measurement range to completely cover the calibration-module laser's measurement range.

2.2. Calibration function and lookup table generation

The role of the calibration process is to refresh the signal to displacement relationships for the *direct* sensors: the calibration module laser, the z-module laser, and the z-sensor. The direct sensors are calibrated against the *indirect* sensor, the LVDT.

In the calibration process, the lower module target can move up and down in the sheet gap, through action of the stepper motor. During a calibration, the dome retracts out of the gap, and then incrementally moves farther into the gap, through the calibration range of the three direct devices. At each calibration point, the signal of the LVDT, in volts, is recorded and translated to a displacement, in microns, with use of the LVDT calibration data (included with the system). Then, for each of the direct sensors, its signal, in volts, is recorded by the MSS. To that signal, the corresponding LVDT displacement is assigned. In this way, one point on the displacement/signal curve for the direct devices is obtained. The target moves a small increment upward, and the displacement assignment process is repeated, establishing another point on the displacement/signal curve for the direct sensors. This process is repeated at typically 150 points through the calibration range of the gauge to generate the full displacement/signal relationships for the direct devices.

The LVDT, the only indirect sensor, ships with a calibration lookup table (LUT). The lookup table is determined in the Honeywell factory and shipped as a supporting text file on the Da Vinci system. Any replacement LVDT assembly is also shipped with a lookup table. The LVDT's displacement to voltage output is almost, but not exactly, linear. The relationship is expressed as:

$$Z_{LVDT}(V_{LVDT}) = Z_o + \left(\frac{dZ}{dV}\right)_{LVDT} V_{LVDT} + Z_{LUT}(V_{LVDT})$$

Equation 2-1 LVDT displacement/signal relationship

For computational efficiency, the nonlinear displacement function is divided by the best fit slope, so Equation 2-2 is rewritten as:

$$Z_{LVDT}(V_{LVDT}) = Z_o + \left(\frac{dZ}{dV}\right)_{LVDT} (V_{LVDT} + V_{LUT})$$

Equation 2-2 Simplified LVDT displacement/signal relationship

The LVDT LUT appears as a single column text file. The descriptions of the entries are stated in Table 2-1.

Table 2-1 Lookup table format

Element	Entry description	Units
0	The number of LUT entries per volt of signal. [dN/dV].	[V]-1
1	Signal value corresponding to the zeroth entry in the LUT, V_0.	[V]
2	Number of entries in the LUT.	[N/A]
3	The offset, Z_o, of Equation 2-2	[μm]
4	The best fit slope, $(dZ/dV)_{LVDT}$, of Equation 2-2	[μm/V]

Element	Entry description	Units
5	Enumerating from 0 to N-1, this is the zeroth entry of the LUT.	[V]
…		
N+4	Enumerating from 0 to N-1, this is the (N-1)-th entry of the LUT.	[V]

In practice the lookup table is employed in the following way: the MSS reads a signal value, in volts, from the LVDT conditioning hardware. This value is V_{LVDT} in Equation 2-2. V_{LVDT} is used to identify which LUT entry should be used for as VLUT in Equation 2-2. The specific LUT entry index, *n*, is computed as:

$$n = \left(\frac{dn}{dV}\right)(V_{LVDT} - V_0).$$

Equation 2-3 Determination of LUT index for a measurement

Thus, the n^{th} corrector value is extracted from the LUT array and included in Equation 2-2 to report the displacement, Z_{LVDT}.

Section 4.4 details how to execute this calibration through the Da Vinci software.

In general, a successful calibration shows near linear responses for the upper and calibration head lasers and a smooth parabolic-looking shape for the z-sensor relationship. Sharp discontinuities in the signal/displacement relationship suggest a problem. As well, the slope and offset of that particular calibration run are presented in the **Calibration Coefficients** space on the display. The value of the calibration slope can be an indication of device health. Nominally, the slope of the laser displacement/signal function should be 152 μm/V (±4 μm/V) for both the z- and calibration-module lasers. Larger values of displacement/signal slopes—approximately 155 μm/V and higher—can indicate the accumulation of dust on the triangulation windows. The z-sensor typically has a slope the order of 350 μm/V (±50μm/V).

It is possible that Da Vinci may present a misleading slope calculation if the direct device is not fully in range during the calibration. For example, if the sheet gap is too wide or too tight, a properly functioning NCC gauge can appear to be malfunctioning. If the region through which the target moves at calibration does not align well with the measurement ranges of the other devices, the device calibration could represent a portion of deadband and a portion of valid calibration. If the portion of deadband is included in the calibration, the calibration will show a linearly sloped portion and a flat portion, the nonlinearity will appear large, and the slope will be outside the guidelines suggested above. Correct evaluation of the calibration slope by eliminating the dead-band can be performed by changing the fit limits in the NCC setup menu or by exporting the calibration and fitting a curve in an external program (see subsection 4.2.2).

2.3. Standardization

The standardization function for the NCC gauge occurs as with the other gauges in the system. During a standardize event, the dome moves to its standardize position, by default the same as the onsheet position, then the flag toggles into the flag/hole aperture, and the gauge measures the caliper of the plastic sample. Like other sensors, the standardize operation is intended to provide an indication of device drift and a means to recover from it.

NOTE: For systems with RAE 4 and updates below 10 the ability to have a standardize position different from the onsheet position can be obtained through a software patch.

3. Gauge Installation and Setup

A large number of NCC sensors are sold into scanners that are already installed at site. This section assumes that the sensor is to be retrofitted into an existing scanner. If the system arrives integrated in the factory, skip to Section 3.2.2.

The section divides the activity into items to be carried out before sensor delivery and activity to be done once the actual gauge arrives. Table 3-2 provides a summary of the actions, time, and materials necessary to install and optimize the sensor.

3.1. Pre-gauge arrival activity

3.1.1. Decide which NCC module to install in which scanner head

Before the gauge is delivered to site a decision needs to be made as to the optimum configuration of the gauge in the scanner. The NCC gauge can be installed with cal-module in the scanner upper head and the z-module in the lower head or vice-versa. The factors that govern the assessment are measurement quality and risk of sheet contact.

In general it is preferable to install the cal-module in the upper head of the scanner. This is because:

- measurement stability appears to be better with the cal-module in the upper head.

- the lower beam of the scanner is more likely to vibrate vertically than the upper beam. It is preferential to have the cal-module mounted in the head that is the most stable as the cal-module tends to pull the sheet along with it and will be more likely to induce the sheet to oscillate.

- If there is any risk of contacting the sheet it is from the calibration module that protrudes into the gap. The z-module is flush with the sheet guide. Thus, if there is a side of the sheet that is more important to protect, select the configuration of the gauge so the z-module faces the most delicate side.

- If there is a side of the sheet that is more at risk of incomplete drying and soiling the sheet guide, the z-module should face this side. In the event of a major soiling the z-module is easier to clean than the cal module.

3.1.2. Prepare the scanner to provision compressed air to the NCC gauge

There are several air-consuming devices in the NCC gauge. In the z-module the following air-consuming device exists:

- z-module purge. The purpose of this purge is to prevent contamination from degrading the performance of the z-module laser optics. It can consume up to 275 SCFH.

In the calibration module, the following air-consuming devices exist:

- calibration module purge. The purpose of this purge is to prevent contamination from degrading the performance of the cal-module laser optics. It can consume up to 275 SCFH

- calibration module air clamp. The purpose of the air clamp is to position the sheet for measurement. It can consume up to 400 SCFH.

- calibration module flag actuation. The purpose of this device is to toggle the flag. It consumes negligible flow, but 40psi is required for actuation.

- Calibration module vacuum. The purpose of this device is to remove dust from the volume between the keyhole plate and the flag. Currently this device has not been used in the field.

If the gauge is to be integrated into an existing field system, the compressed air system will have to be adapted to accommodate the new air consuming devices.

Consult scanner engineering for an air distribution layout proposal, especially on scanners with a large population of air breathing devices. Engineering can propose an air system layout to optimize the air provisioning among the family of gauges on the scanner. An example proposal is shown in Figure 3-1.

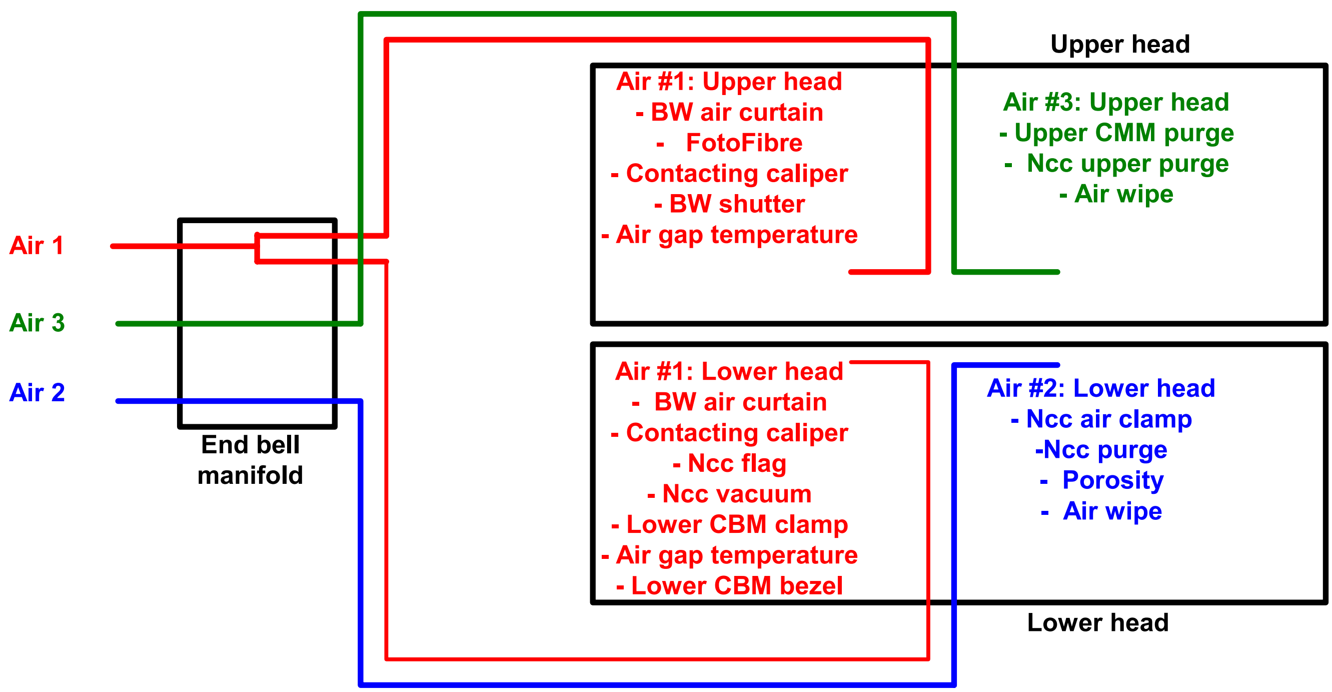

Figure 3-1 Air layout for scanner with large gauge population

When an air system proposal is obtained for the specific installation in question, it may be determined that a third provisioning air line is required. If the third air line is required, the third external regulator is mounted proximate to the scanner ahead of the sensor arrival and at sensor installation compressed air routings on P/N 6580800006 are changed as shown in Figure 3-2.

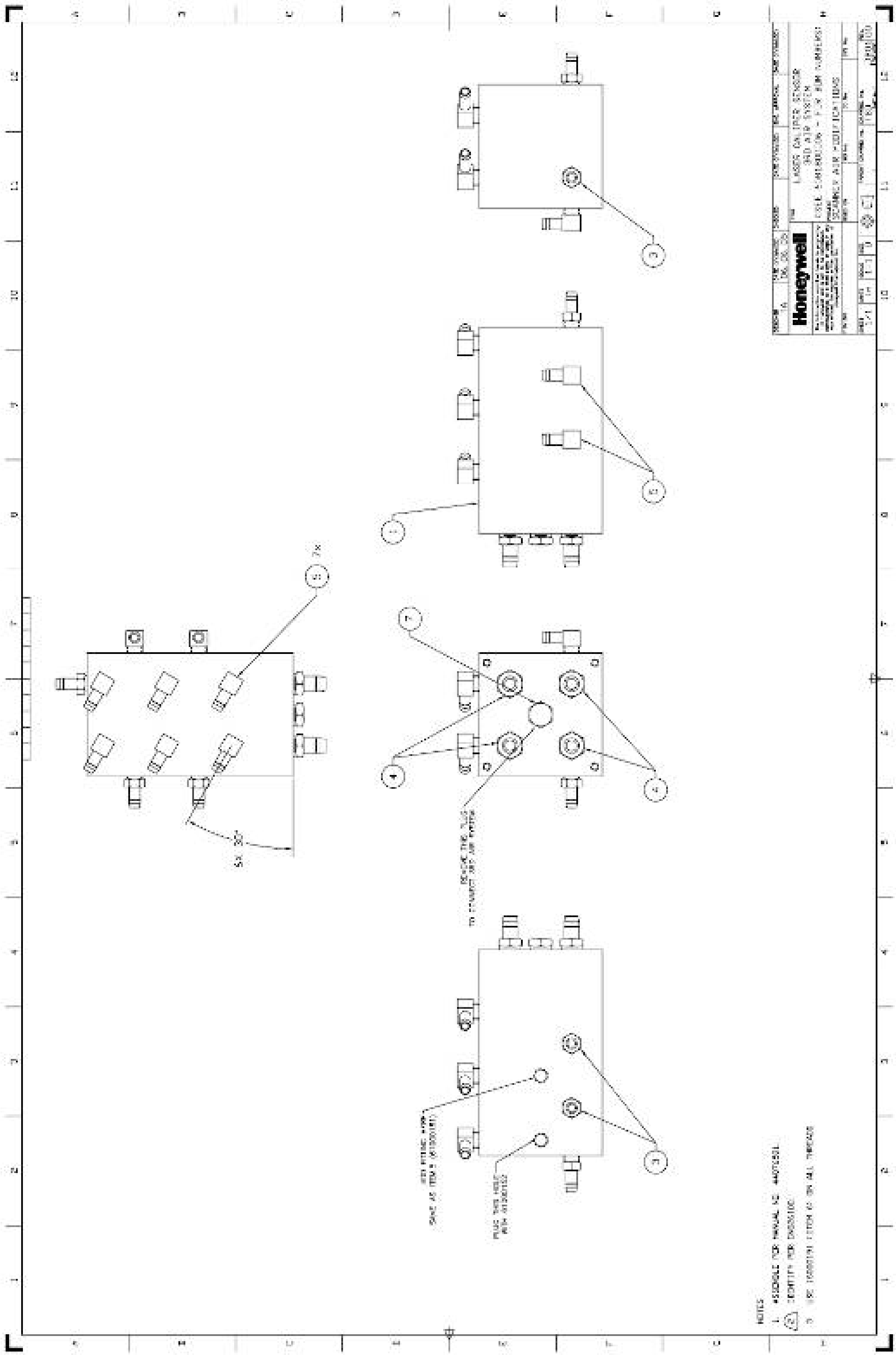

Figure 3-2 Modifications to endbell manifold to route third air line

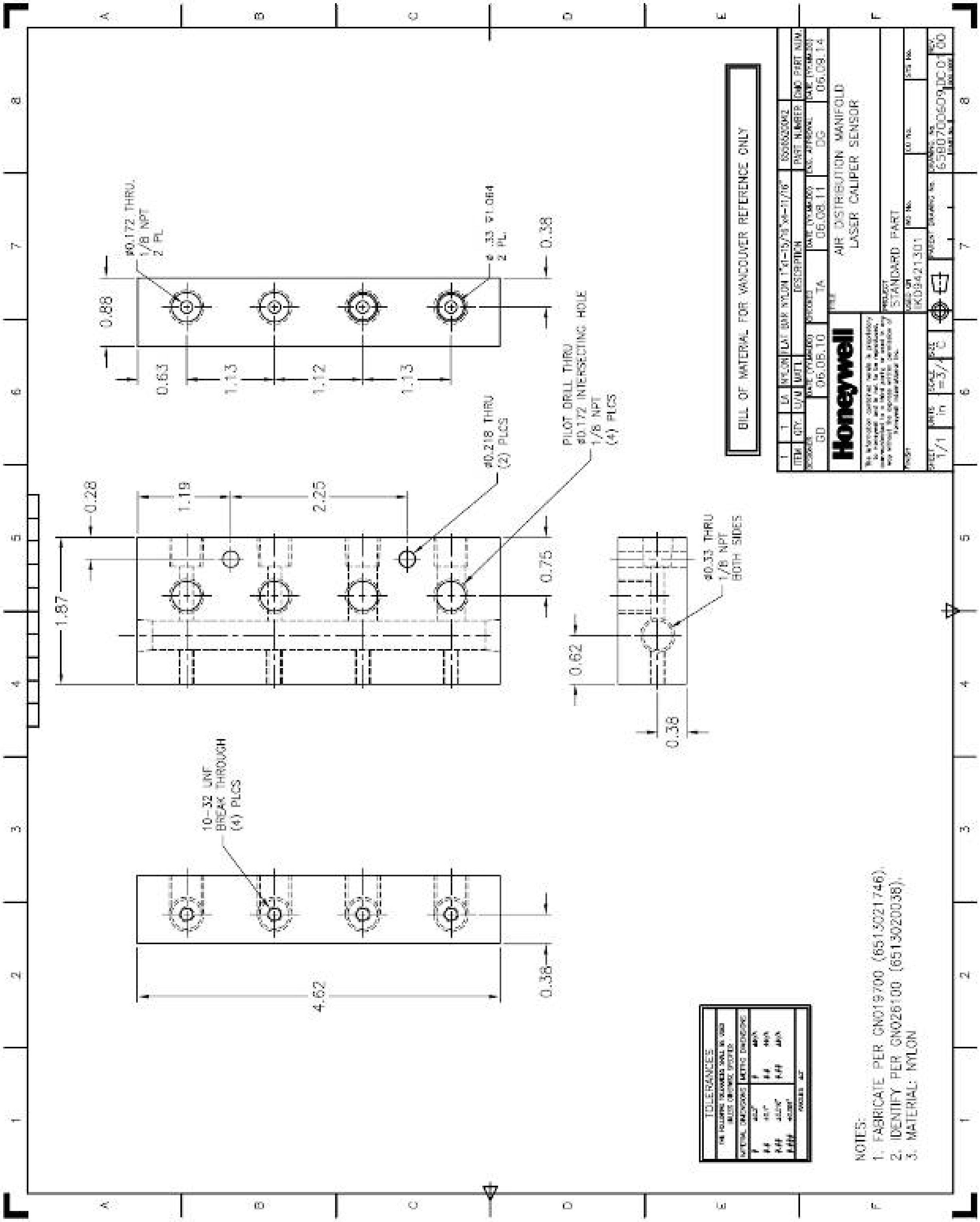

Figure 3-3 Modified manifold and the scanner head (6580700609)

As well, one manifold at each scanner head is needed to be swapped out and replaced with 6580700609.

Examine the system specific air provisioning schematic and determine where the air clamp, cal-module purge, and z-module purges will be connected. P/N 6580700609 is intended to be used to provision the air clamp and the two purges.

In Figure 3-3, the two lower orifices of the manifold have larger cross sections. This is to permit higher flows if required to the air clamp. Attach the air clamp hose to the larger diameter position on the manifold. Two manifolds are supplied to facilitate a sensor inversion if necessary.

3.1.3. Ensure Da Vinci software is up to date

NCC requires at minimum RAE 4 update 9 with additional updates. As this sensor uses SDAQs, assign the channel numbers in the configuration browser. Use the assignments from the system production release.

3.1.4. Install keyswitch elements

Install a keyswitch on the laser caliper system. To upgrade a 4000 scanner to include a keyswitch two items are required:

- P/N 09846300. Laser power keyswitch kit, and
- P/N 05441000 subject to deviation 1334. PCBA, Scanner endbell config F modified for NCC keyswitch, or P/N 6580500091, 6580500092, and 6580500093, the new Config G board set.

The keyswitch can be mounted at either end of the scanner. It attaches to the motor end touch panel cable assembly (6580800055) or the cable end touch panel cable assembly (6580800144). Before the sensor's arrival at site, follow the installation instructions in document package 09846300 that describe the mounting hole requirements in the scanner endbell panel to mechanically install keyswitch assembly 09846300. During a scanner power-down period, wire the keyswitch to cable 08715100 according to document package 09846300 and also replace the endbell configuration card if required.

3.2. Gauge commissioning

3.2.1. Mechanical installation

Before installation, verify that the CML and ZML are emitted close to the centre of their emission holes. Do this with the laser power off and look for the centre of the keyhole slot. Mark on the base plate a reference to the centre laser bracket position. This will simplify later alignment. Also ensure that all the bolts are tight, especially the ones holding the CML to its bracket, holding the cal-mod bracket to the base plate, holding the ZML to the coil form, holding the coil form to the translating frame, and the z-mod translating frame to the base plate. The z-module can be installed with any orientation, but ensure that the thumb screws on the laser alignment stage can be easily accessed.

Install the calibration module in the selected scanner head such that the air clamp emits the air jet parallel to the sheet. The Coanda slot should be upstream of the measurement hole. See Figure 3-4.

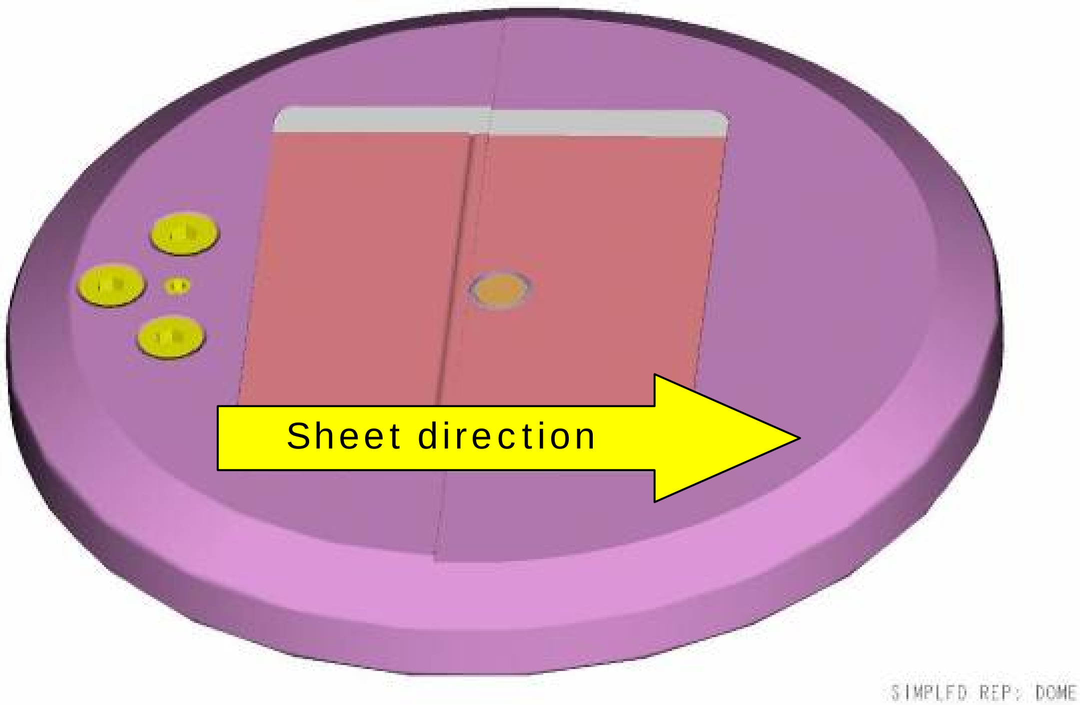

Figure 3-4 Air clamp module installed with step upstream of measurement hole

Ensure proper centering by running a shim or feeler gauge (of thickness less than 0.125 mm (5 mils)) around the periphery of the target. Ensure that the vertical movement of the dome is smooth. This is required for smooth travel during calibration.

3.2.2. Electrical installation, power up, and basic commissioning

Before installing the sensor ensure that all cables are correctly attached to the PCBA, especially the ones for the SDAQ since these are unkeyed, and the ones to the Z-sensor TEC and the ZML heater since these are easy to confuse.

Turn off the scanner to connect the NCC electrically. Depending on the configuration (z-module in upper head and calibration module in lower head or the opposite) ensure the correct installation cable is being used (see Table 3-1). The same cable set can be used in either configuration. If a different board set is being used the cables must be custom made.

Table 3-1 NCC harness p/ns for use with Config F and G boardsets

Config Board Set	Module	Scanner head	Installation cable p/n	Cable Kit
F	Z-module	Upper	6581800093	6509888800
	Calibration-module	Lower	6581800094	
	Z-module	Lower	6581800103	6509888700
	Calibration-module	Upper	6581800102	
G	Z-module	Upper or Lower	6581800141	-
	Calibration-module	Upper or Lower	6581800140	

Start the scanner. On the Da Vinci display, the two laser power digital inputs should be ON. If this is not the case, it is likely that the interlock is not satisfied and the lasers are not enabled. See Subsection 7.1.1 for tips on troubleshooting the interlock. The laser keyswitch should be enabled. For future scanner models (4000-02 and 4000-23) the radlight panels will have a light producing the same output as the LEDs on the laser boards and the Da Vinci display.

After the MSS has verified that the interlock is satisfied, the gauge undergoes an initialization routine in which the dome retracts to the home position, resets an internal counter, and then finally positions the dome at the user-selected **onsheet** position as defined by the **Master Volts for Onsheet Position** in the **NCC Setup** display.

If the dome does not conclude initialization by arriving at the onsheet position, somehow the initialization routine has failed. If there is a staging error presented in Da Vinci. See Subsection 7.1.8 to understand and debug staging errors. Otherwise see Subsection 7.1.6.

Once the gauge is physically installed, powered-up, enabled, and the MSS start up procedure has been observed, the basic functionality of the gauge should be confirmed. The recommended procedure for this is:

- Verify that all temperatures are within range.

- Perform a calibration to confirm dome movement functionality and measurement signal functionality.
- Perform repeated reference to validate the stability of the gauge.
- Perform scanning on flag to ensure basic functionality.

3.2.2.1. Verify all system temperatures are in range

View the **Laser caliper** display to determine at a glance if the NCC temperatures are functioning correctly (Figure 3-5).

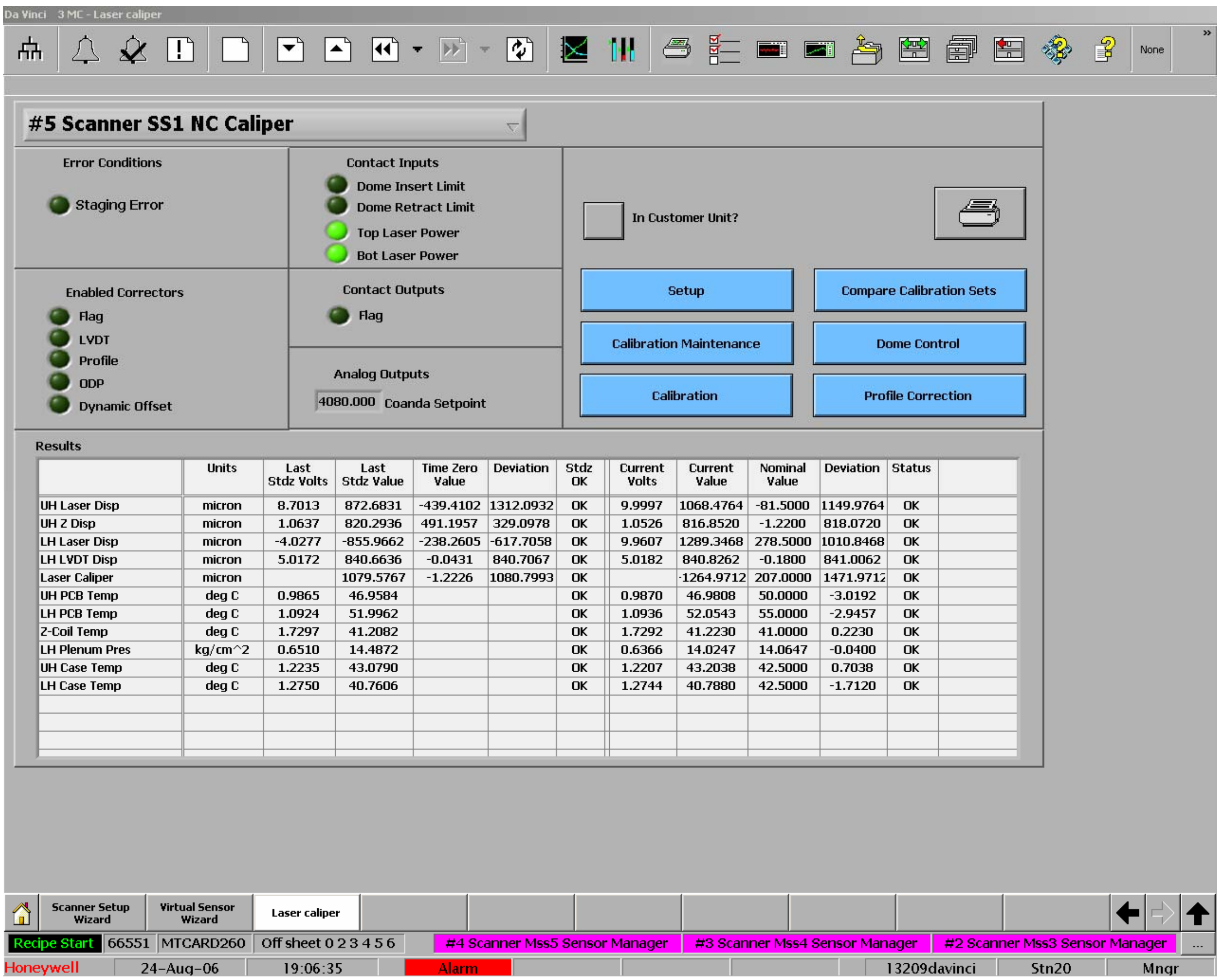

Figure 3-5 Expected temperatures and temperature voltages

There are five temperatures on the laser caliper gauge, three of which are temperature controlled.

The mechanical cases of the two laser triangulation units (ZML and CML) are temperature controlled. These items are listed as **UH Case Temp** and **LH Case Temp**. Both these devices have the same control system and setpoints. A functioning laser heater unit produces a signal level of 1.22 V to 1.26 V corresponding to a temperature between 44ºC to 41ºC. If the signal levels are correct but the engineering units in error, ensure the calibration parameters are correct in Da Vinci. If a signal reads +2.5 V, a thermistor is likely in open circuit condition. This could mean the thermistor is not plugged in securely to its position in the interface PCBA, or the thermistor itself has failed. To directly test a thermistor, obtain a resistance of 20 kΩ at 25ºC and 10.6 kΩ at 40ºC.

The z-coil ceramic (z-coil temp) is temperature controlled by two thermoelectric coolers. This setpoint should stabilize to between 41ºC to 44ºC with signal levels of 1.78 V and 1.66 V respectively. If the signal levels are correct but the engineering units off, ensure the calibration parameters are correct in Da Vinci. If the signal reads +5 V, the thermistor is likely in open-circuit condition. This could mean the thermistor is not plugged in securely to its position, or the thermistor itself has failed. Be aware that there are two thermistors embedded in the z-coil ceramic which, when working properly should be reporting very similar temperatures. One signal is routed to Da Vinci for reporting purposes and the other signal is routed to the control circuitry on the ZM-PCBA for feedback control. For example, a broken monitoring thermistor can lead to Da Vinci reporting the incorrect temperature of the z-coil while the coil is actually at the correct temperature. In the alternate case of the feedback thermistor failing, there is no possibility that the z-coil is at the correct temperature. To verify that the thermistors are functional, measure the resistance across pin pairs (J1-1 and J1-2) or (J1-3 and J1-4) each of these should measure approximately 2.2 kΩ at 25ºC and 1.3 kΩ at 42ºC. The temperature of a properly functioning device should vary by no more than 0.2ºC.

The PCBA surface temperatures are uncontrolled and vary more widely than the controlled temperatures. Typically, these temperatures are higher than the ECU-measured temperature in the scanner head. Expect temperature measurements between 40ºC and 60ºC (0.84 V and 1.26 V respectively). These temperature-sensing devices are integrated into the PCBA surfaces themselves and cannot be serviced in the field.

3.2.2.2. Execute a nominal calibration to ensure all displacement measuring devices are functional

See Section 4.3 for the loading procedure for the LVDT lookup table into the Da Vinci system. Once this is done, follow the detailed instructions of Section 4.4 to perform a calibration and save the results to disk.

Verify from the NCC calibration display that all direct device graphs show a signal to displacement response and that this response is smooth and continuous outside the deadbands.

Review the slopes (A1) for all direct devices in the NCC Calibration display, see Figure 3-6. The offsets, (A0) can depend on the thermo-mechanical breathing of the scanner heads and will be somewhat arbitrary. Expect slopes like:

Z-module laser	(152 ± 4) μm/V
Cal-module laser	(152 ± 4) μm/V
Z-module Z-sensor	(330 ± 50) μm/V

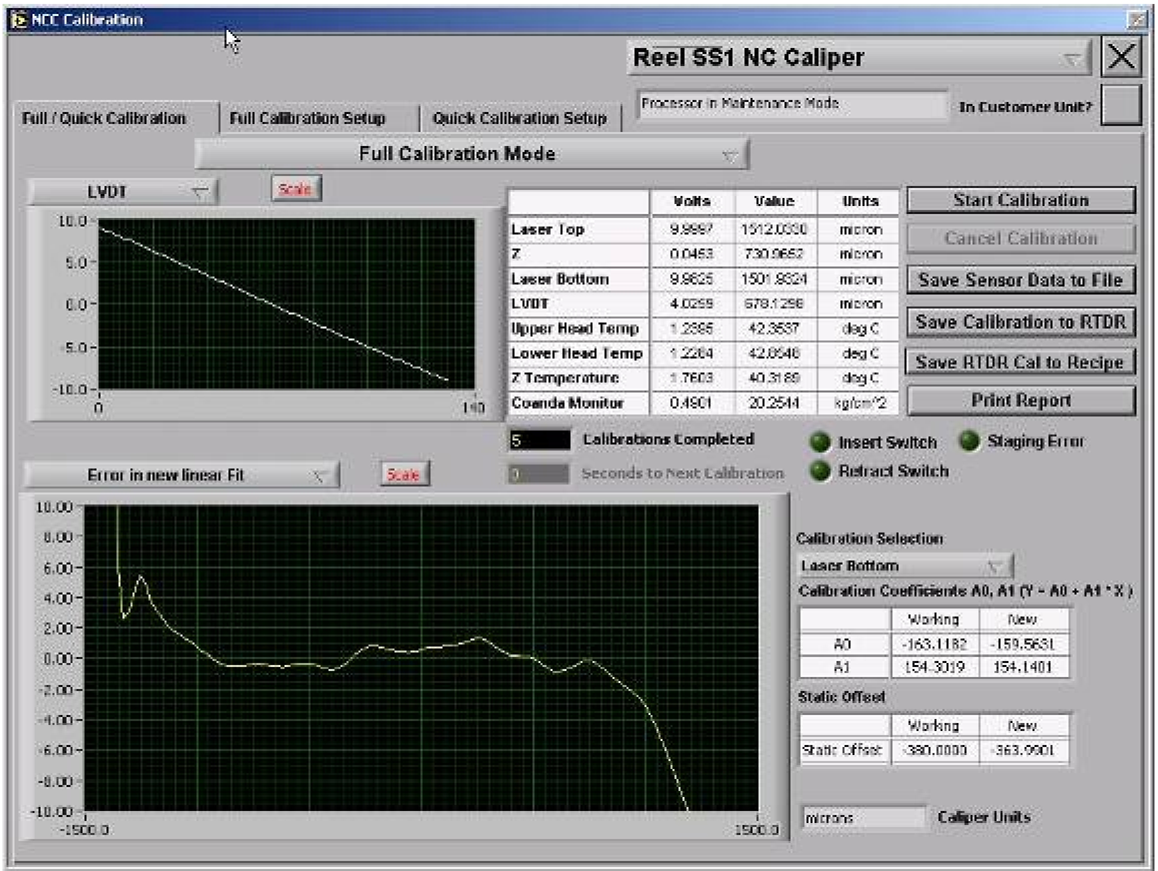

Figure 3-6 Review calibration slopes: A1 is the slope and A0 is the offset

Save the calibration file to the hard disk for use later when an onsheet position is to be estimated.

3.2.2.3. Check gauge stability and flag toggling repeatability

To verify gauge stability, execute an appropriate number of repeated standardizes to ensure device measurement and flag toggling repeatability is sound. Put the scanner in maintenance mode and do the repeatability test through the sensor maintenance display as shown in Figure 3-7.

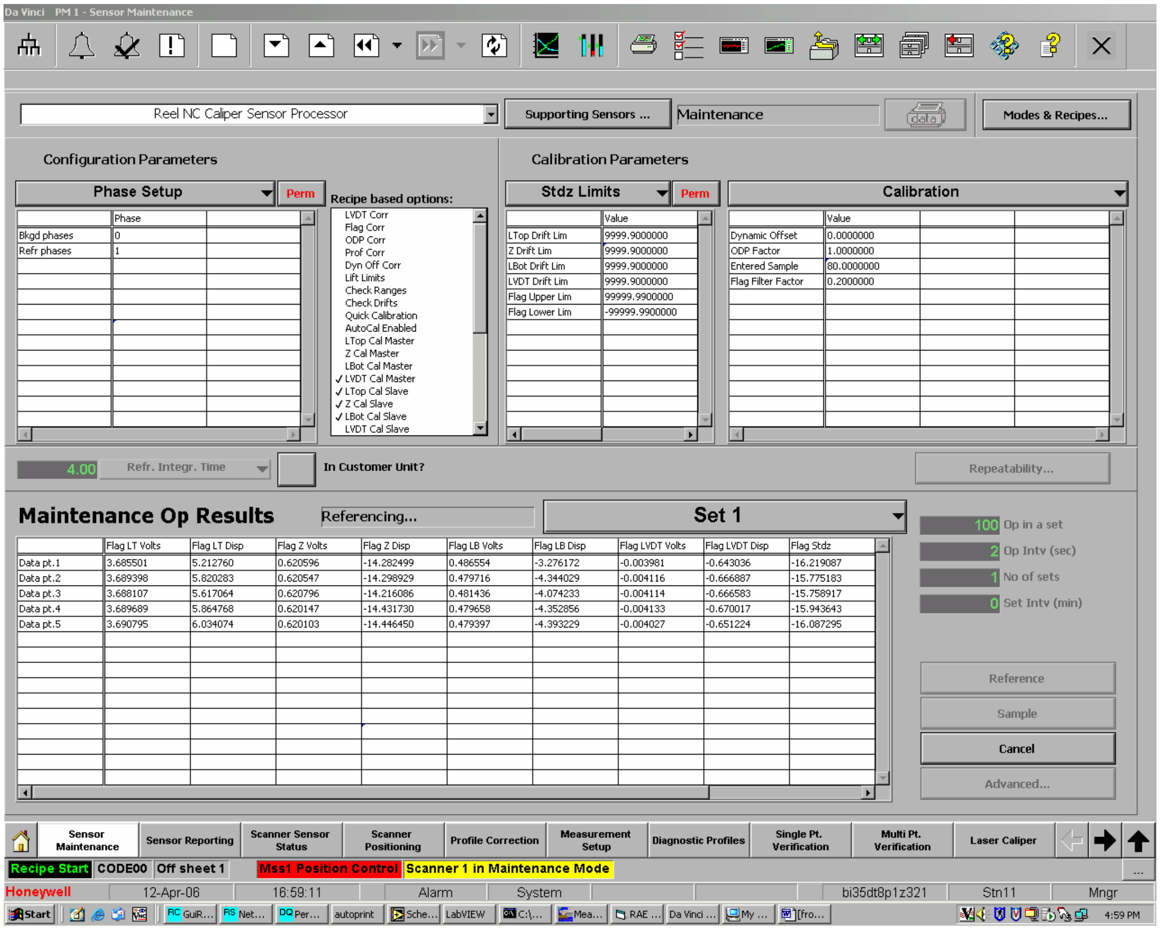

Figure 3-7 Repeated reference setup

Perform the test with the following parameter assignments:

Field	Value
Integration time	4.0 seconds
Op in a set	100
Op Intv	2 seconds
No of sets	1
Set Intv	0 minutes

During the referencing, visually verify the flag is indeed toggling. After the references are complete, verify that the 2-sigma repeatability of the **Flag Stdz** column is less than two microns.

Maintenance Op Results Idle (Reference) **Set 1**

	Flag LT Volts	Flag LT Disp	Flag Z Volts	Flag Z Disp	Flag LB Volts	Flag LB Disp	Flag LVDT Volts	Flag LVDT Disp	Flag Stdz
Data pt.92	3.851172	-2.567850	0.687190	-1.963041	0.462986	0.387995	-0.000709	-0.063223	0.216814
Data pt.93	3.850957	-2.605643	0.686544	-2.179753	0.462899	0.374673	-0.001915	-0.276851	0.051217
Data pt.94	3.848357	-3.009166	0.685710	-2.456350	0.464814	0.675140	-0.002521	-0.384313	-0.122323
Data pt.95	3.847672	-3.114206	0.685706	-2.457695	0.464203	0.581216	-0.001501	-0.203547	0.075295
Data pt.96	3.849214	-2.872992	0.686122	-2.319831	0.463053	0.404546	-0.001620	-0.224566	0.148615
Data pt.97	3.847303	-3.170766	0.686434	-2.216253	0.464027	0.554159	-0.001376	-0.181418	0.400355
Data pt.98	3.848486	-2.989280	0.686427	-2.218603	0.462754	0.352369	-0.001079	-0.128660	0.418307
Data pt.99	3.847492	-3.141835	0.686208	-2.291360	0.463636	0.494094	-0.000271	0.014518	0.356381
Data pt.100	3.846877	-3.240842	0.686524	-2.186574	0.464368	0.606533	-0.000889	-0.095069	0.447735
Average	3.855259	-1.933485	0.690503	-0.860844	0.464193	0.580445	0.000419	0.136637	0.492196
2 Sigma	0.017009	2.648730	0.004685	1.559873	0.011813	1.851683	0.001854	0.328618	0.485288
Max - Min	0.030162	4.697101	0.010367	3.451201	0.023302	3.654590	0.005306	0.940321	1.530693

Figure 3-8 Results of repeated standardize (flag toggling)

If the spread is too large, attempt to identify which device is contributing most to the instability. View the individual spreads of the CML, ZML, and z-sensor displacements. If one is disproportionately larger then the rest, that is the likely unstable device. It is possible that the Flag. Stdz spreads can be lower than the individual device spreads. This is the normal behavior of a working gauge if, for example, the head separation changes during the flag toggling (as they are likely to do if the scanner heads have just been moved offsheet). In this case, the z-sensor and the ZML may properly report displacement excursions that are large, but if they tend to cancel each other the system stability is acceptable.

Another potential reason for poor repeatability is if the flag repositions poorly during the testing. Evidence for this would be large variation on all of the devices: ZML, z-sensor, and CML. To repeat the test without the flag toggling, the flag toggling can be stopped by physically disconnecting the flag air supply or re-routing the flag jobset strobe in Da Vinci. Such a test with a stable flag will give an immediate picture of the repeatability of the constituent measuring devices and the relative stability of each one.

3.2.2.4. Verify temperature stability

Once the head is at temperature, verify that the laser case temperatures and z-coil temperatures are stable to better than ±0.1°C. Select a time span of at least one hour. The head covers have to be present and the heads have to be up to operating temperature for this to be a valid test. At room temperature, accurate control of the laser case temperatures is not expected because the heaters are not able to heat the lasers cases to 42 °C. At scanner ECU setpoint of 40°C, the heaters can easily hold the laser cases at 42 °C.

3.2.2.5. Perform flag scans

The scanner can easily be made to scan on the flag by toggling the **Measure with Flag** item on the **Recipe based options** list on the **Sensor Maintenance** tab of Da Vinci. Alternatively, a maintenance code can be made with the same effect. Scans on the flag do not look the same as those on a moving sheet since there is no averaging of the surface micro-roughness of the flag. Expect 2σ values less than 5 µm. If the values are higher than this, try recalibrating the sensor. Figure 3-9 shows an example of flag scans.

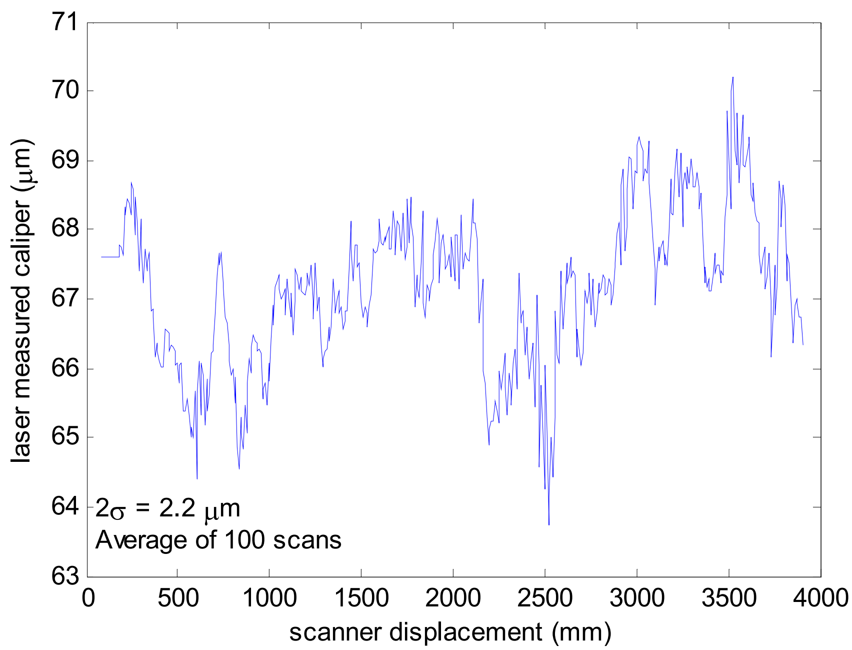

Figure 3-9 Laser caliper profile measuring on flag

3.2.3. How to determine the optimum on sheet position for the dome

Each device on the laser caliper has a measurement range. Use the calibration file that was previously saved to disk (see Subsection 3.2.2.2) and the spreadsheet file 6509421301PT02 from the CD shipped with the laser caliper to estimate the overlap range of the measurement devices. Following the instructions on the **instructions** tab of *6510030033PT01.xls*, cut and paste the contents of the calibration text file into a copy of template *6510030033PT01.xls* and a graph similar to Figure 3-10 is generated. On the x-axis of the plot, the dome displacement as given by the LVDT is shown; on the y-axis, the device signals are presented.

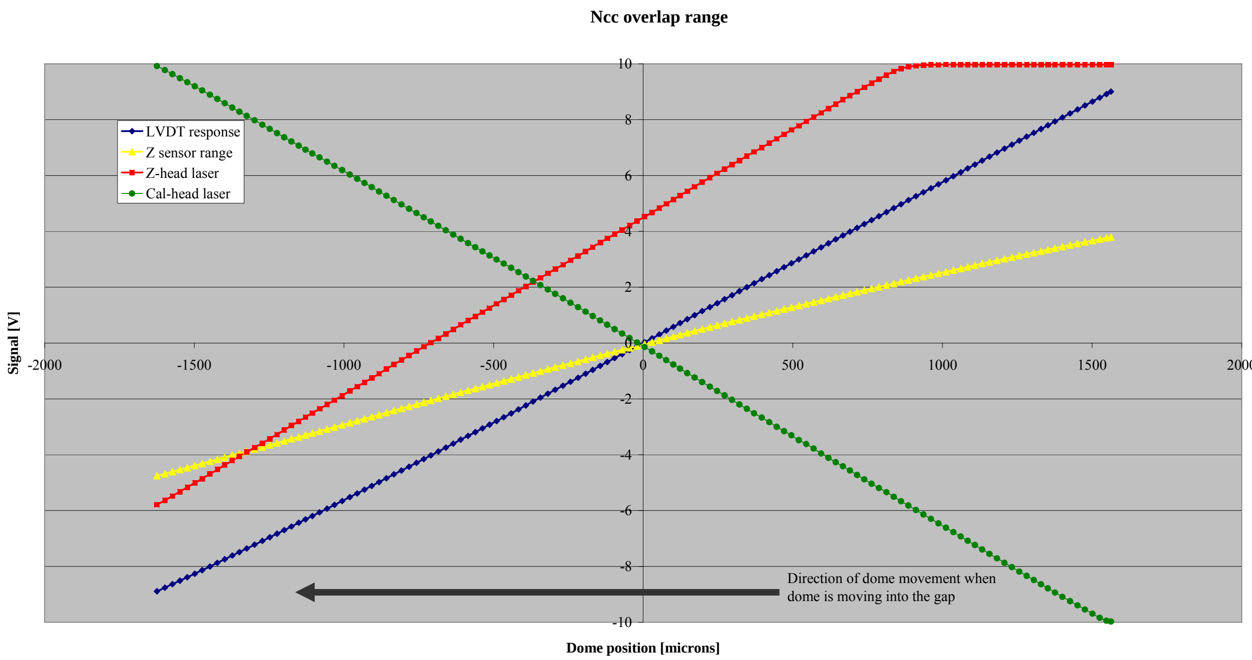

Figure 3-10 Overlap range plot generated from *6510030033PT01.xls*

Interpret the graph as: the x-axis shows the displacement as given by the LVDT and the y-axis shows the signal given by each device as the dome moves through its calibration range. The dome can be imagined to travel from right to left as it moves through the calibration (The dome's retract limit - or HOME position when is pulled into the calibration module - can be imagined to sit off the scale on the far right of the plot. The insert limit would be on the far left of the plot). Use this plot to select a good onsheet position. Consider these criteria:

- The stainless steel target must be comfortably inside the calibration range of the z-sensor with margin to accommodate the level of vertical head gap oscillation of the scanner,
- The sheet should be comfortably inside the measurement range of both optical devices,
- It is desired that all devices are in range at standardize[2].

[2] A patch is available for RAE 4 systems that allows for a standardize position different from the onsheet position. This will be standard in future versions of Da Vinci.

In the example, the onsheet position of +800 μm is a good choice for this system. Imagine a vertical line on this plot at +800 μm. This vertical line intersects all four curves at the following signal levels: +5 V for the LVDT, +2 V on the z-sensor, +9 V for the CML and -5.5 V for the ZML. If a more retracted onsheet position were selected, it would soon be out of range of the CML at standardize.

The sheet can be imagined to lie to the left of the +800 μm vertical line. Predict approximately 500 μm to 1500 μm to the left depending on the customer product and air clamp flow rate parameters. The signal levels for the ZML and CML when they view the sheet will be different from when they view the flag. Once the sensor is running on the moving sheet, record a typical signal level from the ZML and CML. Go back to plot Figure 3-10 and using the signal levels from the laser displacement sensors, visualize where the sheet is being held relative to the flag. Ensure that the sheet is comfortably in range of the triangulation sensors across the CD scan.

3.2.4. Likely profiles for z-module laser, calibration-module laser, z-sensor, and LVDT

The activities suggested in the previous section will determine the likely nominal signal and displacements from each of the calibration head laser, z-module laser, z-sensor and LVDT. This section outlines the likely variation about the nominal levels and how to determine what is normal.

Consider first how the sheet is held. The air clamp exerts an aerodynamic force on the sheet and sucks it toward the calibration head. This has been observed to be true even when the calibration module scanner head has vertical movement due to system vibrations. In fact, the expected variation of the sheet position with respect to the air clamp is lower than the expected variation of the separation of the heads themselves. This has been observed to be true even when the calibration module’s scanner head has the most absolute motion.

Beware of vibrations of the scanner, as their amplitudes can change dramatically in time. If dominant frequencies appear in the head separation profile that correlate to the tens of Hertz, be aware of potential resonances. The gauge is designed to endure resonances but large variations on the order of ±1 mm can induce sufficient overlap range degradation that the direct sensors will be out of range. The expected variations are:

- The z-sensor variation will measure the head separation explicitly. Typical z-variations will be between ±100 μm and ±500 μm depending on the scanner alignment. Make a distinction between a stable scanner with a fixed head separation profile and a scanner that is vibrating.
- As the sheet tends to travel with the calibration head, the z-module laser will tend to report a similar profile to the z-sensor. Expect variation of the order of between ±100 μm and ±500 μm as well depending on scanner stability.
- The sheet can be held to within ±50 μm relative to the calibration module's dome. CD specific deviations in this profile are very likely due to local tension changes across the sheet or deliberate physical interferences with the sheet, such as guide bars at edges or dragging anti-static chains.

3.2.5. How alignment and sheet position influence measurement quality

Alignment is a critical issue for the NCC gauge. (see Figure 3-11). Imagine two optical triangulation lasers are probing opposite sides of a sheet at slightly different points in space. If the sheet is non-flat and the two triangulation lasers are not mutually aligned, the difference in height of the sheet between the two triangulation points will be reported as pure error in the NCC measurement.

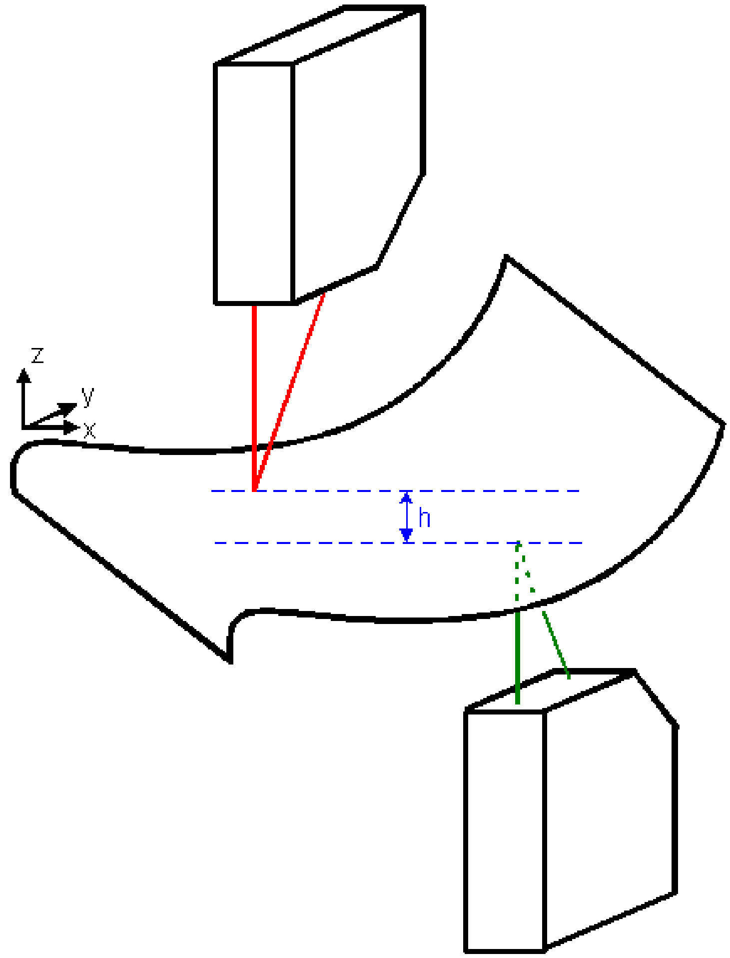

Figure 3-11 How misalignment and non-flat sheet lead to caliper measurement error

For quality measurement performance:

- The sheet needs to be as flat as possible to minimize the impact of inevitable scanner head wander.
- The two optical triangulation devices need to be mutually aligned other at a preferential position for measurement.

The design of the gauge includes the patented Coanda air clamp in the calibration module. A flow emerges from the Coanda slot and exhausts, at high velocities, parallel to the sheet direction (it is because of the geometry internal to the Coanda that the flow is induced to exit parallel to the dome surface and not perpendicularly from it). This flow controls the sheet relative to the air clamp. The profile of the calibration head laser displacement, as a function of cross-direction, is actually a representation of the variation in the sheet position relative to the air clamp surface. It is routine to see cross-directional peak-to-peak variations in the calibration module laser bounded within ±200 µm—this literally means the sheet can be held to within a fraction of a millimeter tolerance relative to the air clamp during cross-directional scanning.

It is first useful to get a sense of what airflow should be used for the air clamp. A recommended starting point is to use a plenum pressure of 5 psi or lower. This value will depend on the orientation of the heads (is the air clamp in the upper head or lower head) and the weight of the sheet. It is expected that heavier sheets may require more aerodynamic force to position them[3]. Perform some brief system evaluations. Set the plenum pressure to an initial guess and allow the scanner to scan. Observe the calibration-module laser's displacement profile. Does it show spikes as if the sheet is occasionally lifting away from the clamp (see Figure 3-12)? If so, increase the flow through the air clamp so that the spikes are suppressed. As well, the fast transients in sheet flutter can be observed by examining the calibration-module laser displacement in the fixed point frame on Da Vinci. If Da Vinci has the Fixed Point Analysis package enabled, position the scanner at any CD positions of interest and accumulate data at the fastest DAQ rate permitted by Da Vinci. Observe to see if the sheet position is well bounded in magnitude and free of any obvious aerodynamic resonances. Iterate and select a suitable flow though the air clamp.

[3] However, note that for very heavy sheets a greater stiffness can be expected, this means that a good sheet shape may be achieved with a low air-clamp pressure.

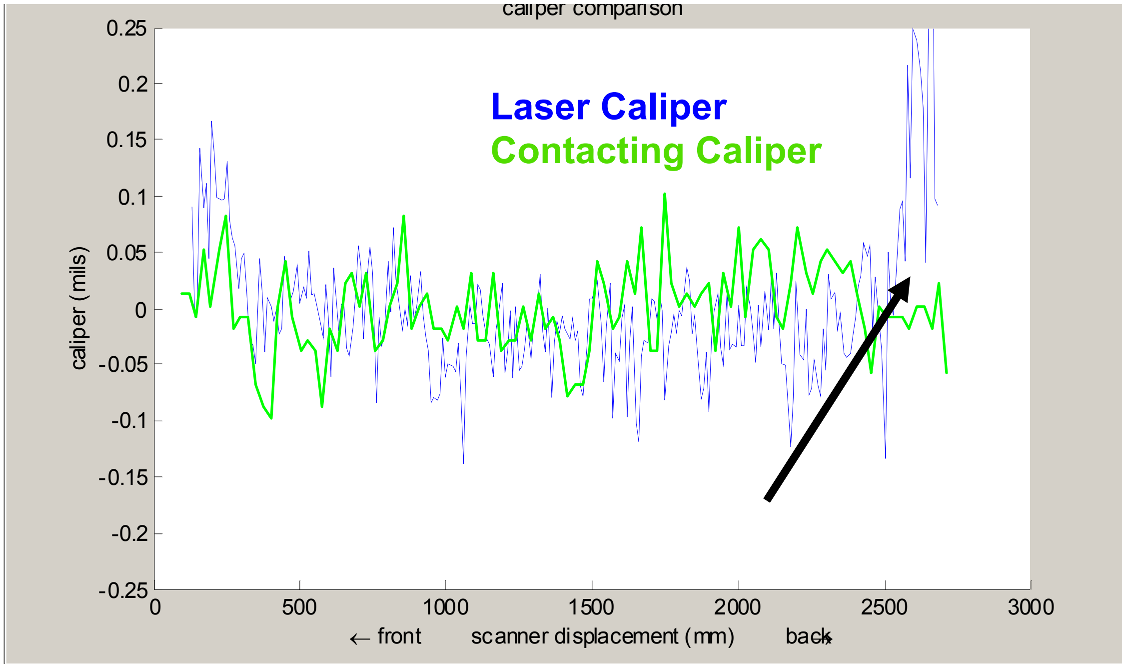

Figure 3-12 Example of insufficient air flow through air clamp

3.2.6. Optimize sheet shape and estimate optimum measurement position

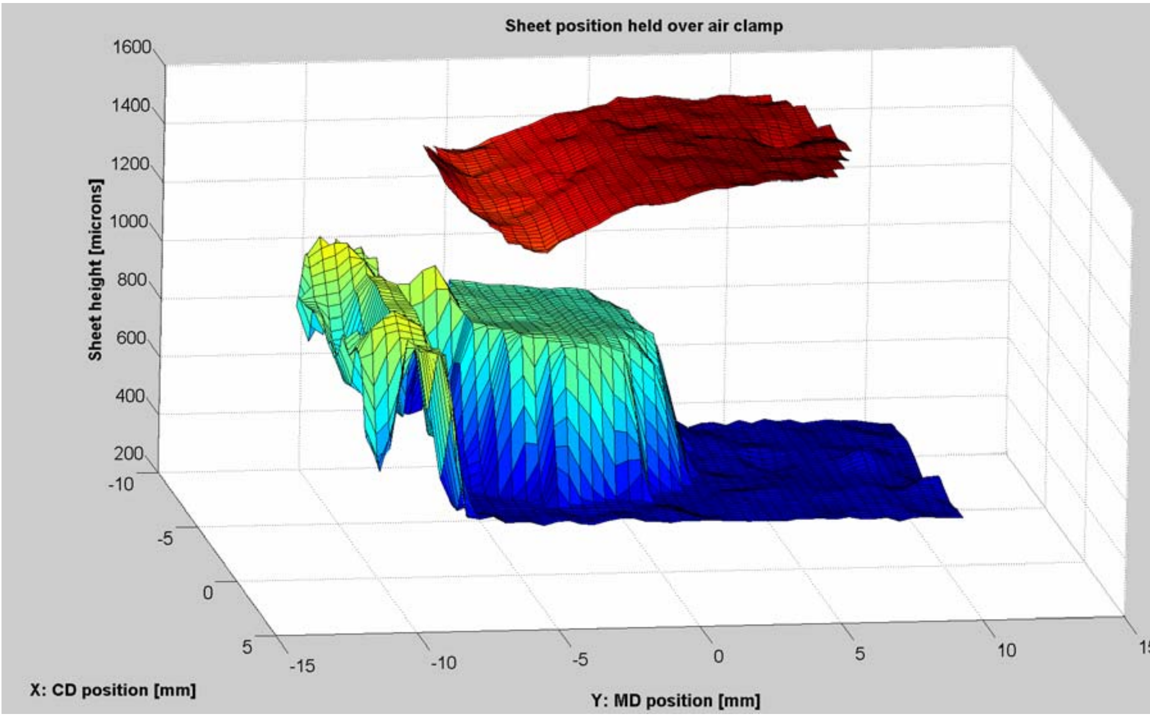

Figure 3-13 Actual sheet positioning influence of air clamp on production sheet

Figure 3-13 shows an example of a typical production sheet as held in position by the air clamp. In the figure, the sheet is shown above the air clamp and the cal-module laser. At the left of the picture is a mapping of the Coanda slot and the backstep. Where there is normally a hole through which the laser measures, there is shown a flag. The laser would normally emit along the centerline of the circular region. The area of the topology is approximately 20 mm in the CD and 10 mm in the MD with total height range of approximately 1 mm. The sheet moves from left to right parallel to the MD axis. The sheet is expected to be pulled down and reach a minimum, coincident, or slightly upstream, of the center of the laser output orifice.

Optimize the air clamp at installation. The sheet positioning system has two goals:

- To pull the sheet minimum into a position accessible to the optical triangulation devices.

- To provide sufficient force to the sheet so the influence of the air clamp is enough to overcome other perturbations such as tension variation across the CD, and basis weight changes between grades.

The following sections suggest methods by which to optimize points 1 and 2. First, a topology of the sheet, similar to Figure 3-14, should be obtained. This is a representation of how the sheet sits above the air clamp as a function of CD and MD and is necessary information to make a good alignment selection.

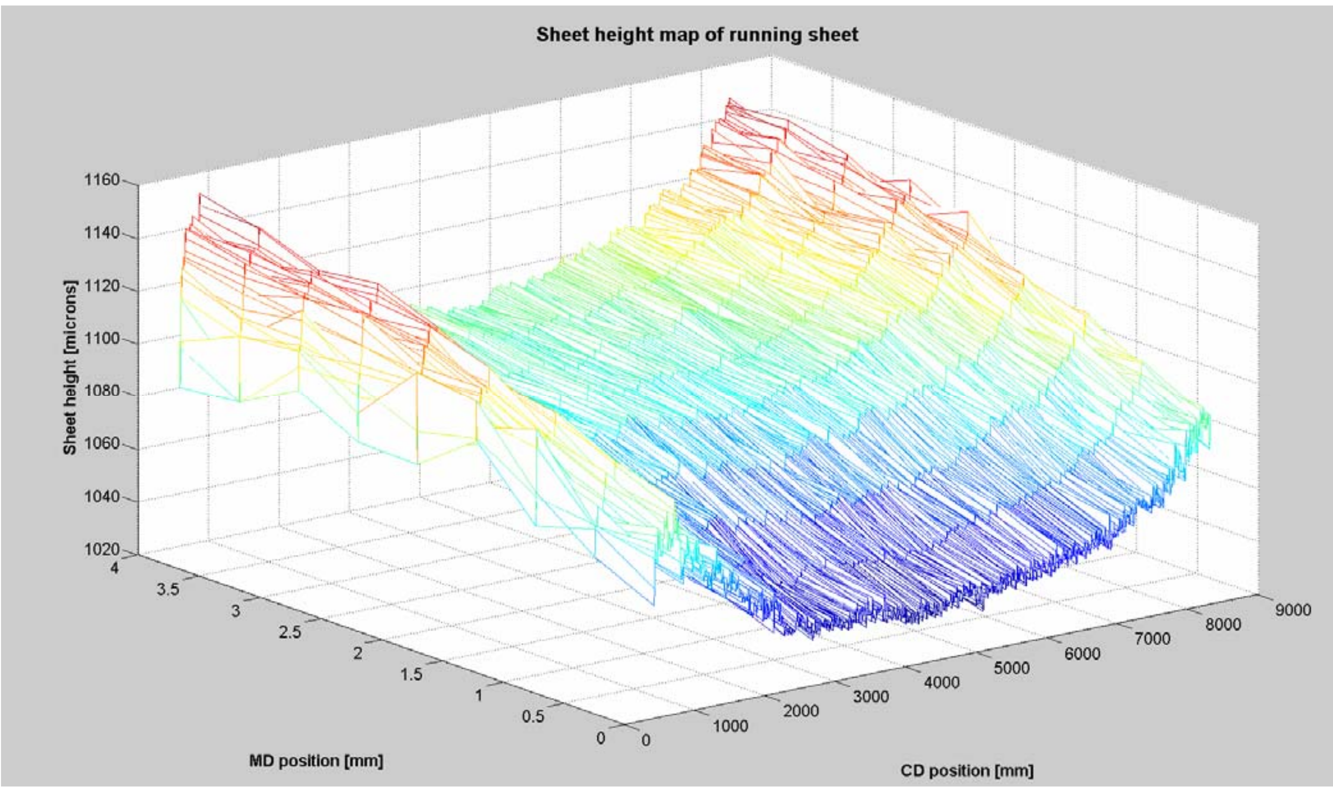

Figure 3-14 Example of 3-D sheet topology over air clamp

Notice the scale on this graph. The vertical scale is in units of microns and describes the relative height above the air clamp of the sheet as a function of both MD and CD.

To gather the data to generate this type of graph, one must iterate the position of the calibration-module laser using the mechanical alignment provisions. See Figure 3-15 to identify the securing and repositioning screw of the calibration module.

Repeat these steps:

1. Move the scanner heads off sheet and open the scanner head containing the calibration module.

2. Loosen the securing screw just enough so that the cal-module laser/LVDT bracket can slide relative to the base plate.

3. Drive the repositioning screw to the extremity of its travel in the MD. The total travel is of the order of 4 mm. Use the feel of screw—i.e. the torque felt from rotating the screw—to determine the travel limit. Do not force the repositioning screw. (It does not matter in which direction the initial extreme position is sought. In later iterations, increment the repositioning screw back in the opposite direction to sample the sheet position as a function of different MD positions). It is possible to position the CML so the beam is obstructed by the flag mechanism. This will be evident from a sudden change in the profiles.

4. Secure the securing screw and close up the scanner head.

5. Activate the datalogger and accumulate scan data, for a dozen scans or so. Include at minimum scan data for the NCC measurement array, the z-sensor displacement array, the cal-head laser displacement array, the z-head laser displacement array, and the LVDT displacement array. Name the datalog file so it can be identified as being related to the specific MD position of the LVDT bracket.

6. Repeat steps 1-5, but at step 3, increment the repositioning screw so that the bracket travels incrementally by approximately 0.5 mm at each sampling. The screw thread is such that one full turn of the repositioning screw equates to approximately 0.65mm of travel. This will have to be repeated eight times to acquire enough data to generate the plot presented in Figure 3-14.

7. It may be possible to speed up this process by calculating the sheet angle and determining which way the sheet is angled. The x and y sensors do not have a predetermined

sign because they can be installed in one of two orientations differing by a 180º rotation. To determine the sign it is necessary to measure the x or y signal (with a trend plot for instance) and push one head with respect to the other. The resulting information should allow one to determine the direction of the sheet angle and determine if the alignment is upstream or downstream of the best position (see Figure 3-17).

Engineering can provide software to assist in developing these plots once the data is gathered.

A cross section of Figure 3-14 is presented in Figure 3-16 and can be used to determine the optimum positioning of the cal-head laser. Seek the flattest region where the paper sits. In the example of Figure 3-16 the most desirable spot appears to be at approximately 2.7 mm, indicated by the red arrow. The sheet sits at an inflection point and the expected error at that location due to MD misalignment of the heads will be minimized. If there is no suitable flat spot, iterate to a different flow rate and repeat the procedure.

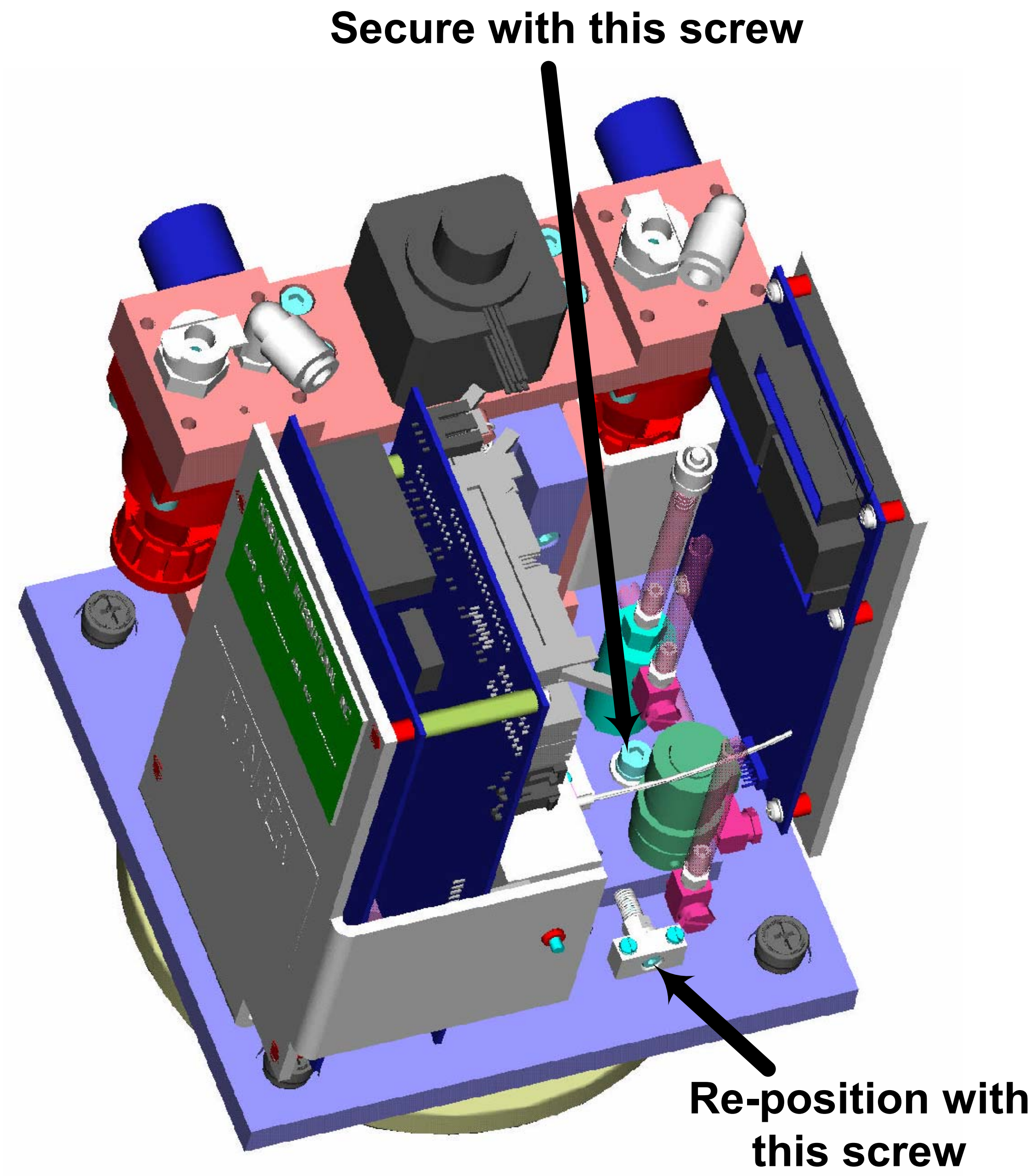

Figure 3-15 Securing and repositioning screws for calibration module alignment

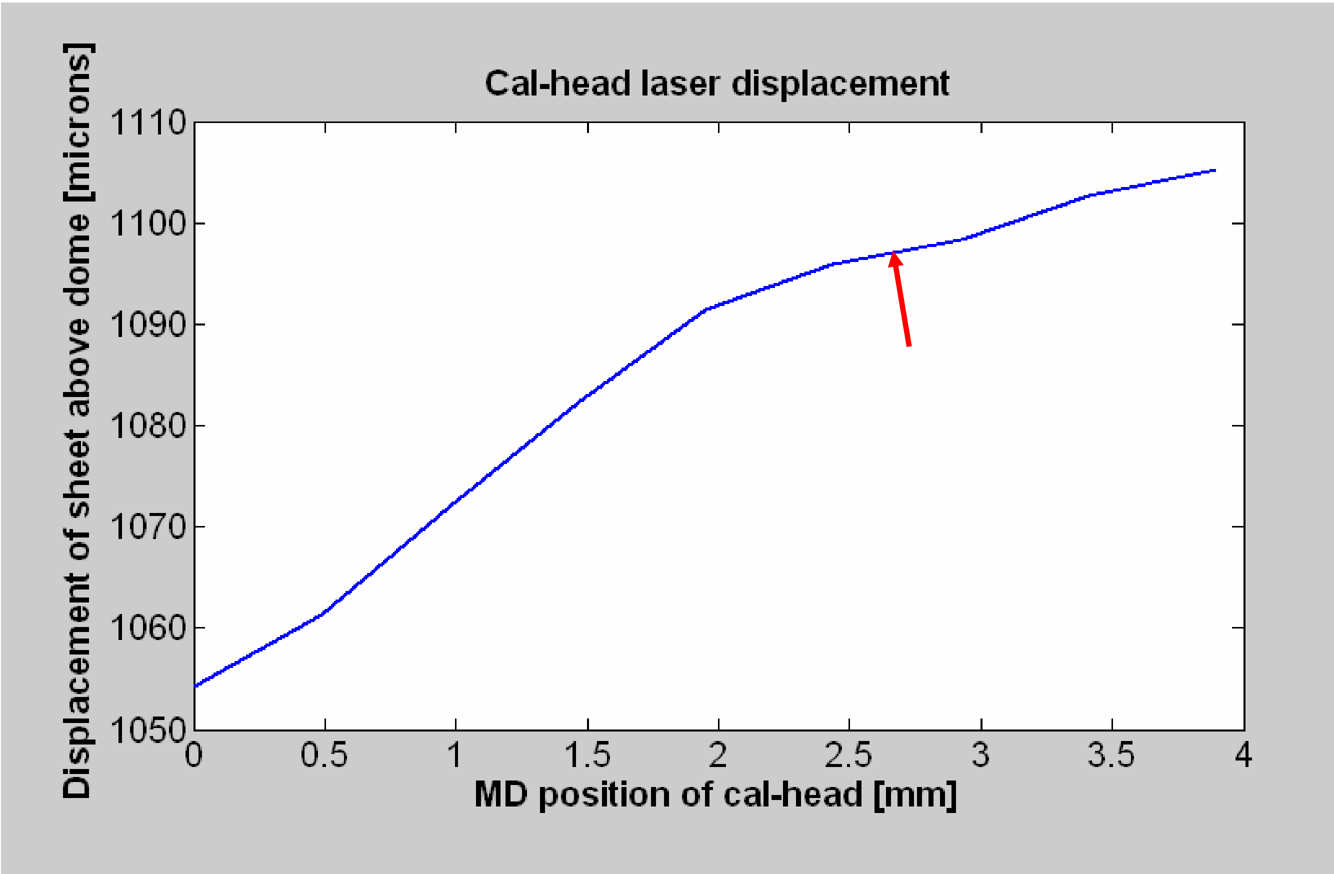

Figure 3-16 MD cross section of sheet topology

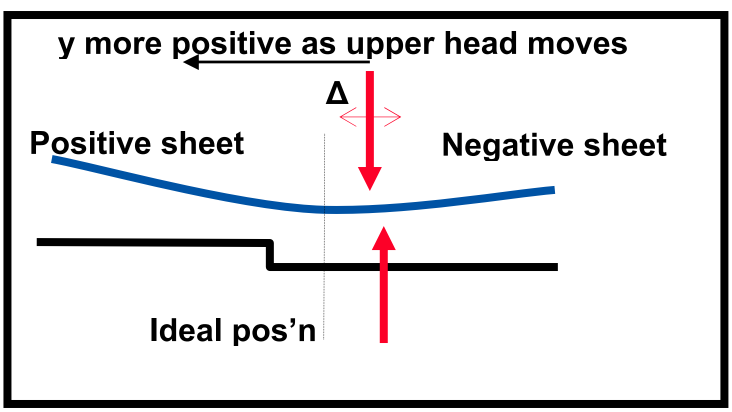

Figure 3-17 Sign of sheet angle relative to the ideal measurement position

3.2.6.1. Optimization of angle by dome position

In some situations it may be possible to optimize the laser caliper profiles by adjusting the dome position. This is most likely to be the case on a high tension sheet or with some sheet control device, such as rollers, installed on the scanner. Figure 3-18 shows an example. Here the sheet angle and the profile goodness could be optimized simply by adjusting the dome position. If this technique is effective, it is likely to be more so if the laser alignment is adjusted prior to a dome height adjustment.

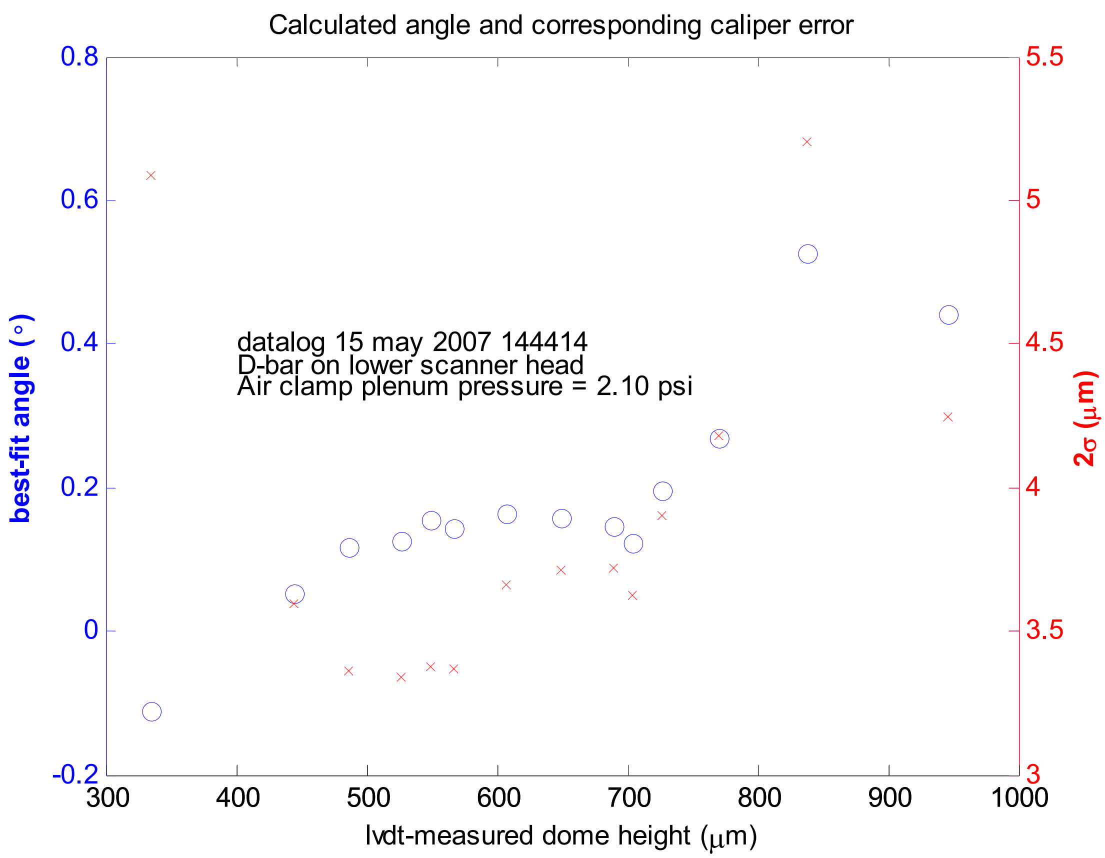

Figure 3-18 Example of sheet angle relationship to profile quality

3.2.6.2. To mutually align lasers using alignment tool

Once the CML position has been fixed, the laser caliper alignment tool is used to mutually align the lasers.

1. Once the calibration-module laser has been positioned into the optimum position for measurement, the next step is to use the alignment tool to mutually align the z-module laser to the position of the calibration-module laser. The broad strategy for this alignment is described. Keep it in mind as the steps of this section

are performed. The details of the alignment tool operation and the z-module mechanics will follow.

2. The position of the calibration-module laser has already been established in the previous step. There is no need to move it again.

3. Before mounting the alignment tool, use Da Vinci to check that the flag is retracted so that both lasers can see into the gap and retract the calibration-module dome to the retract (or home) limit. This is required to pull the dome out of the gap and allow clearance for the alignment tool. As well, it may be useful to stop the airflow from the air clamp as the aerodynamic forces from the air clamp are sufficient to bend the insertion tongue. Furthermore, if the alignment is going to take more than approximately 10 minutes, the air wipes should be disconnected. If the PSD is too hot the performance may suffer.

4. Install the alignment tool through mounting bolts onto the lower scanner head sheet guide so that the PCBA tongue (extension) protrudes into the sheet gap and the PSDs are approximately in line with the laser sensors. The alignment tool parts can be identified using Figure 1-18.

5. If it is the first use of the alignment tool, it will be a good idea to mount the alignment tool on the lower head with the heads split. Center the PSD over the laser in the lower head. Large movements to the MD position of the PSDs can be made by adjusting the position of the PSD extension with respect to the alignment tool translation stage using the insertion adjustment screw.

> The alignment tool must be removed before the heads are un-split as the laser caliper start up procedure will drive the dome into the PSD PCBA. This may cause equipment damage.

6. Align with the scanner in the offsheet position. However, first consider the X and Y profiles of the scanner geometric performance. Verify that the offsheet position is reasonably representative of the onsheet CD profile. The lasers travel with the scanner heads and any variation in MD or CD alignment between the onsheet and onsheet positions of the heads will be transferred to the gauge. If possible, during a sheet break or shut-down, make the alignment at

a CD position that is most representative of the CD variation in X and Y if the offsheet position is insufficient.

7. With the scanner heads together (not split) and the dome retracted. Mount the alignment tool on the scanner and use the translation stage to move the PSDs relative to the calibration-module laser, so that once in place, the alignment tool will serve as a reference for positioning the z-module laser.

8. Once the alignment tool is aligned relative to the CML do not move it again. Only translate the z-module laser after this to complete the alignment.

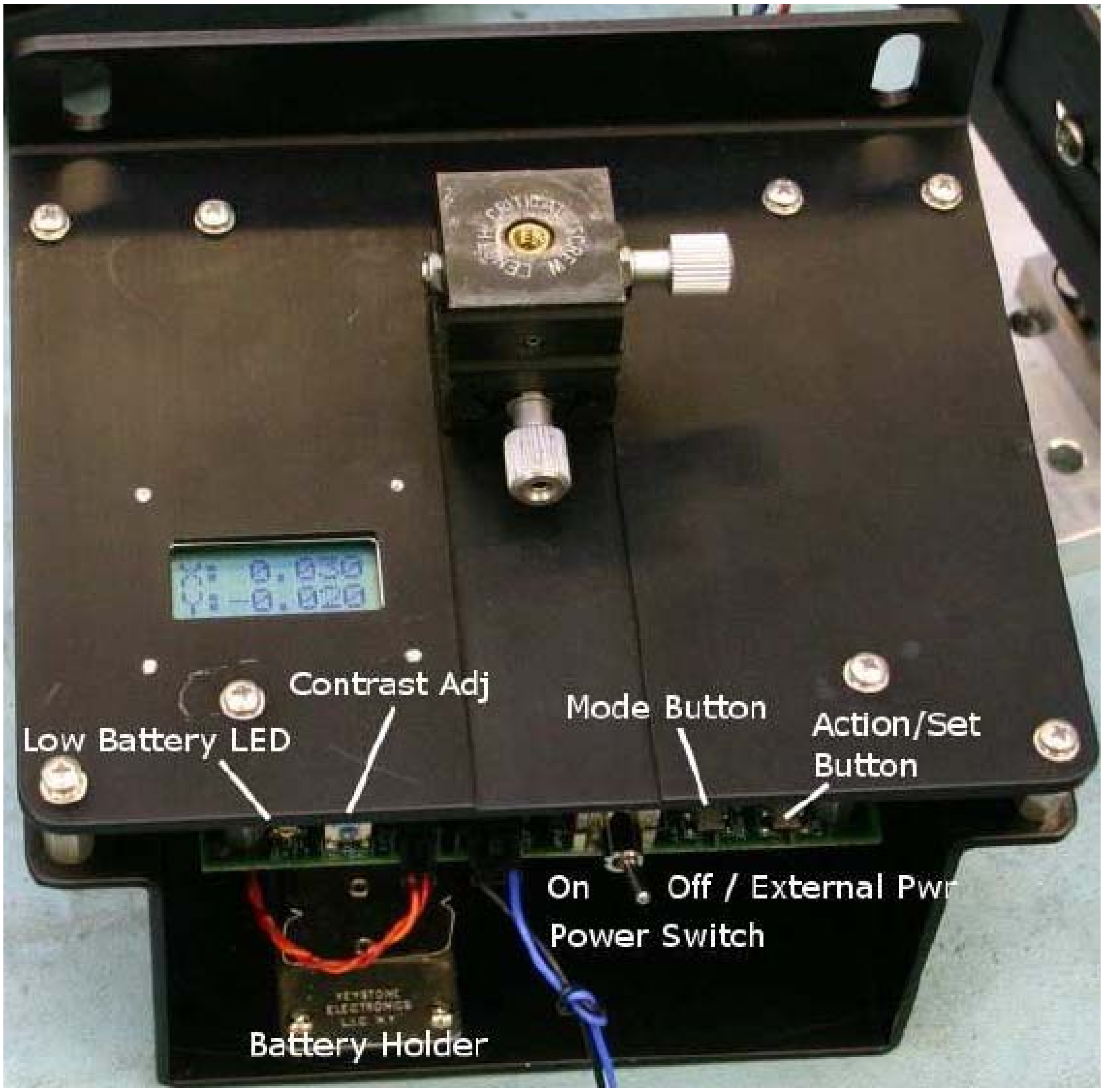

Figure 3-19 Controls and indicators on alignment tool (PSD extension not shown).

9. See Figure 3-19 for location of the controls and indicators of the alignment tool. The alignment tool display panel reports displacements in units of millimeters

10. Power on the alignment tool with the toggle switch.

11. There are three modes of operation for the alignment tool:

    a. **Laser bottom**: the display reports the absolute position of the lower laser beam on the lower PSD with respect to the centre of the PSD, the CD is the X axis and the MD is the Y axis;

b. **Laser top**: the display reports the absolute position of the upper laser beam on the upper PSD; and

c. **Laser top minus laser bottom**: the display reports the difference between the upper and lower positions of the upper and lower lasers.

12. Select **Laser bottom** or **Laser top** mode to measure the position of the CML.

13. Move the alignment tool tongue, using the MD and CD adjustment knobs until the display reads within ±0.03 mm on both axis. Use a 5/64″ Allen key to fit inside the adjustment knob if finger turning is cumbersome. If the display reads **No Laser** it means the laser beam is not sufficiently aligned to the position sensitive detector. Search until a nominal X/Y reading appears on the display.

14. Once the alignment tool PSD is aligned with the calibration head laser, move the z-head laser to complete the alignment. Use the **Laser top minus laser bottom** mode. Iterate until the gauge is aligned to better than ±0.06 mm in both MD and CD. To learn the details on how to move the z-module laser see the following steps.

15. The steps to move the z-module laser and secure it after completion of alignment require a focused set of instructions. Figure 3-20 and Figure 3-21 identify several mechanical features of the z-module specific to alignment. There is a so-called translating frame or dish that can move relative to the base plate. During an alignment, this is the part that will move. Figure 3-22 shows the detail of the inner translating dish. Notice that the z-module optical displacement sensor, the z-coil form, the TECs, and the anti-dust purge assembly all move in unison. Below are the steps to move the z-module laser:

16. Identify the securing clamps which hold the inner translating frame to the base plate (see Figure 3-21). Two are present in the z-module. Loosen both of the clamps using a 7/64″ Allen key. Loosening the tabs is sufficient, it is not recommended to remove them entirely.

17. Once the securing clamps are loosened, move the gauge in the MD or CD as desired using the knobs on the alignment stage. A 5/64″ Allen key can be used to turn the knobs if access does not permit

finger twisting. Never force the translation knob to turn. If there is too much resistance, inspect it for mechanical interferences.

18. Follow the alignment progress by observing the display of the alignment tool and converge to the aligned position.

19. Lock the inner frame to the base plate with the securing clamps. It is possible that the act of tightening the clamps can influence the final alignment. Verify that the alignment remains in specification and if not, iterate until it is satisfied.

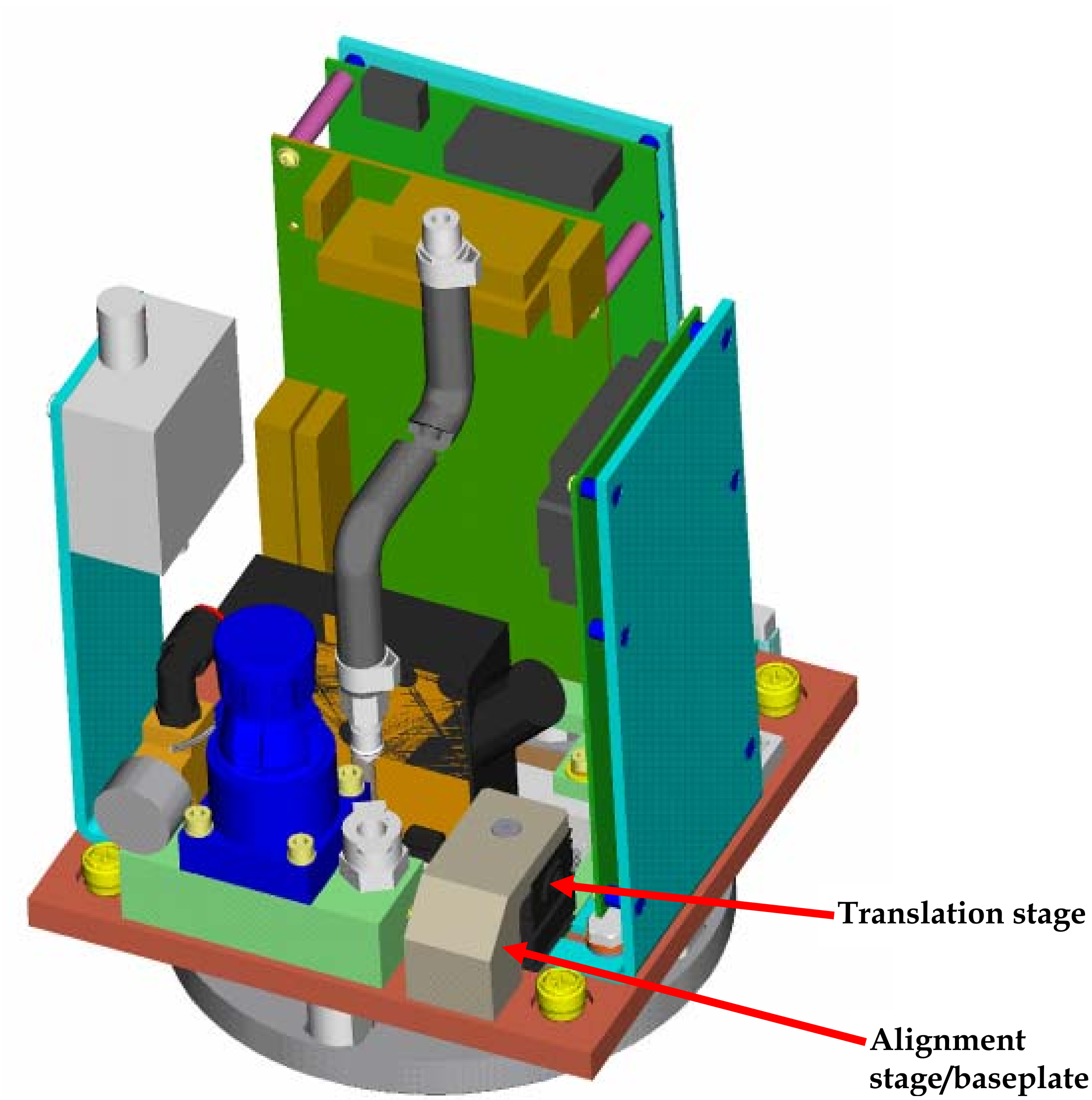

Figure 3-20 Z-module alignment provisioning mechanics 1/2

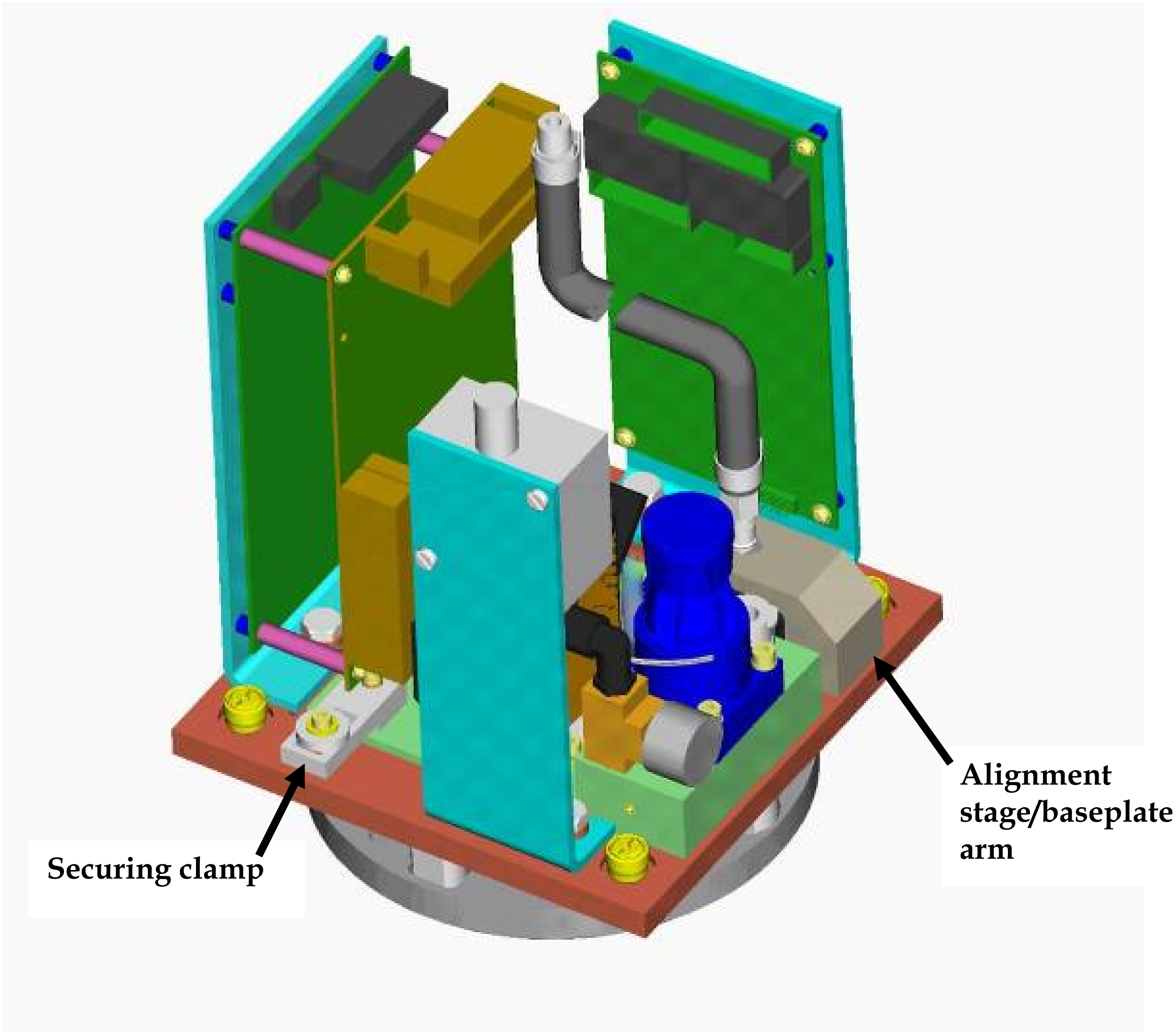

Figure 3-21 Z-module alignment provisioning mechanics 2/2

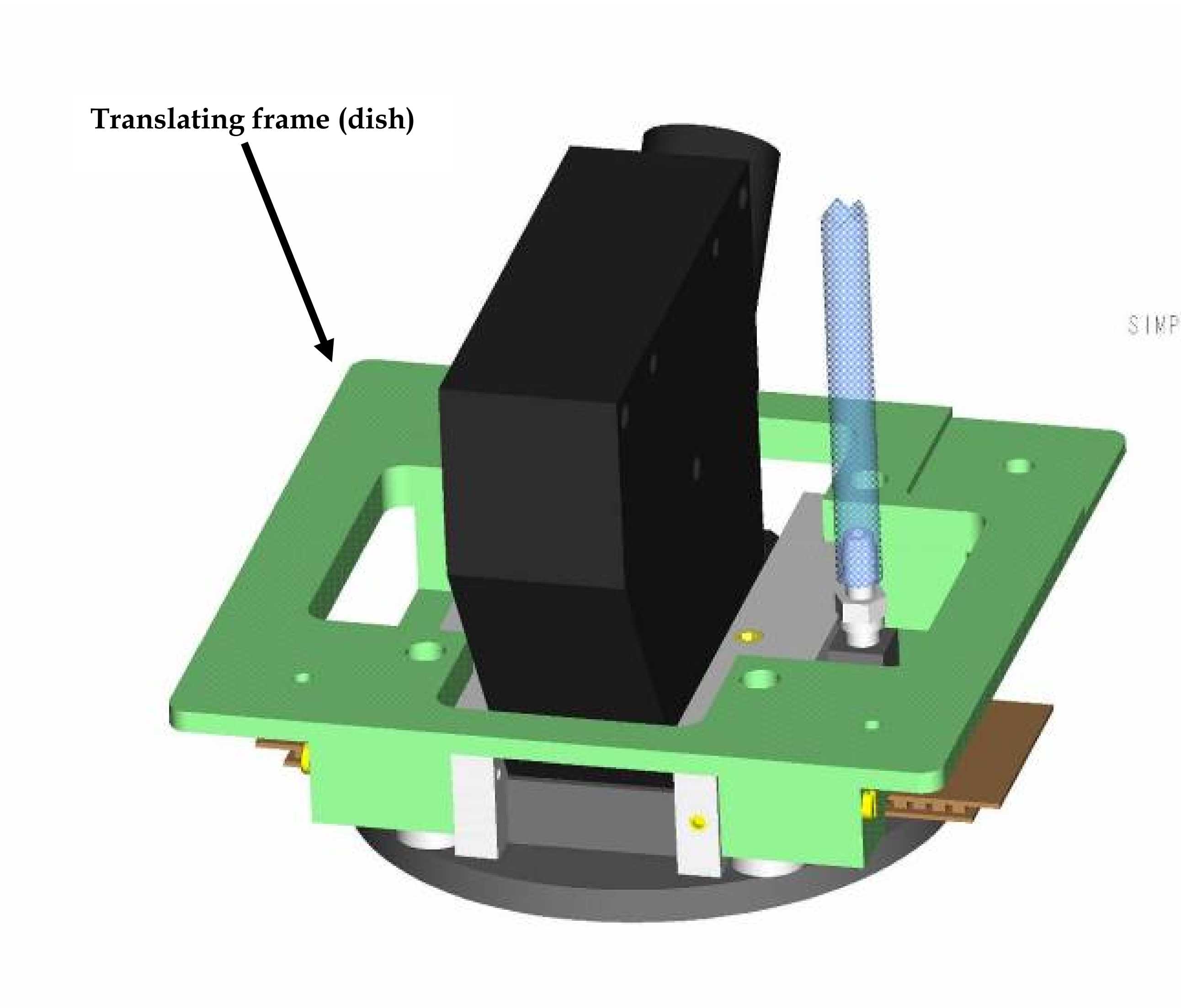

Figure 3-22 Close-up of translating dish and attached measurement devices

20. Once the alignment is complete, re-calibrate the sensor to account for subtle shifts in the z-sensor back-loading and the target profile it sees. Load the renewed calibration into the system for measurement. See Section 4.4 for details on this step.

3.2.7. How to set the static-offset to report the proper absolute value

The absolute value reported by the non-contacting gauge should be adjusted at this time. Up until this point in the commissioning process, all non-contacting sensor absolute values have been relative and have been concerned primarily with profile quality. In general, if there are profile problems, ignore the absolute value until the profile is valid and stable.

Once that is achieved, obtain a measurement estimate of the "true" absolute caliper. A sample of the current product or a comparison with the contacting sensor are both valid means to obtain a true absolute value estimate. When this is obtained, adjust the static offset in the **Laser Caliper Setup** display so the onsheet absolute caliper value is correctly reported. Use this formula to adjust the offset:

New static offset = *Current static offset - Laser Caliper Reading* + *True caliper*.

3.2.8. Collect scanner baseline information

To assist in troubleshooting at a later date, collect baseline information. Most of the data can be collected on the Da Vinci display. Take Screen captures of

- laser caliper display when the scanner has warmed up,
- forward and reverse single and trended scans for caliper, CML, ZML, LVDT, and Z when scanning on the flag and on representative product, and
- flag repeatability data.

Additionally, record the air purge pressures.

To scan on product, paper will have to be attached directly to the face of the dome at as flat an angle as possible. Turn the air clamp off. Other sensors use the sample fin. If the sample fin is to be used for the other sensors the laser caliper dome must be retracted. Do not use the sample fin for a laser caliper sample. The sample fin is not configured for laser caliper, and it is not possible to hold the sample as flat as necessary with a sample fin type arrangement.

Table 3-2 Installation steps and time estimates

Step	Section reference	When	Labor required	Parts required	Comments
Decide on gauge installation (cal-mod upper or lower)	3.1.1	Pre-Gauge Arrival	1 hour	N/A	
Prepare compressed air upgrades	3.1.2	Pre-Gauge Arrival	0-4 hours	9716503 if required	Obtain air provisioning layout from engineering
Ensure Da Vinci Software Current	3.1.3	Pre-Gauge Arrival	0-6 hours	N/A	Install RAE 4 Update 9 or higher with applicable patches--approx. 1 hour per network node.
Ensure Da Vinci settings for Laser Caliper are correct	4.8	Pre-Gauge Arrival	1 hours	N/A	This must be checked otherwise scanner may be forced offsheet.
Install Keyswitch Elements	3.1.4	Pre-Gauge Arrival	2 hours	09846300 (keyswitch) and 05441000 subject to deviation 1334 or the config G board set.	Requires a scanner power-down period of approximately 10 minutes.
Inspect gauge electrically and mechanically and adjust laser positions.	3.2.1 and 3.2.2	Gauge Arrival	1 hour		Doing this will save time later!
Mechanically Install Gauge	3.2.1	Gauge Arrival	2 hours	2 x 6580700609 (LCal Air manifolds)	Requires offsheet time for duration of action.
Power-up and Initial Commissioning	3.2.2	Gauge Arrival	3 hours	N/A	Requires offsheet time for duration of action.
Estimate onsheet position	3.2.3	Gauge Arrival	0.5 hours	N/A	Calculation only. No offsheet time.
Nominal Gauge Alignment	3.2.5	Gauge Arrival	0.5 hours	N/A	Requires offsheet time of 30 minutes.

Step	Section reference	When	Labor required	Parts required	Comments
Air Clamp Flow Optimization and Gauge Alignment Fine Tuning	3.2.6	First Scans After Install	6 hours non-consecutive	N/A	Periodic offsheet time, data collection and analysis. No power down.
Correlation Analysis and Profile Optimization	7.2.2	First Scans After Install	12 hours non-consecutive	N/A	Periodic offsheet time, data collection and analysis. No power down.
Set static offset and collect baseline information	3.2.8	First Scans After Install	2 hours	Paper sample	

4. Da Vinci Software Description

This chapter describes the laser caliper-specific Da Vinci displays. The Da Vinci system includes a dedicated **laser caliper** software tab as seen in Figure 4-1. This tab is available under the **Scanner/Sensor** tab for users with **mngr** or higher status. This display provides an overview of the sensor status, the correctors employed, the last standardize and current values and buttons from which further laser caliper displays are accessed.

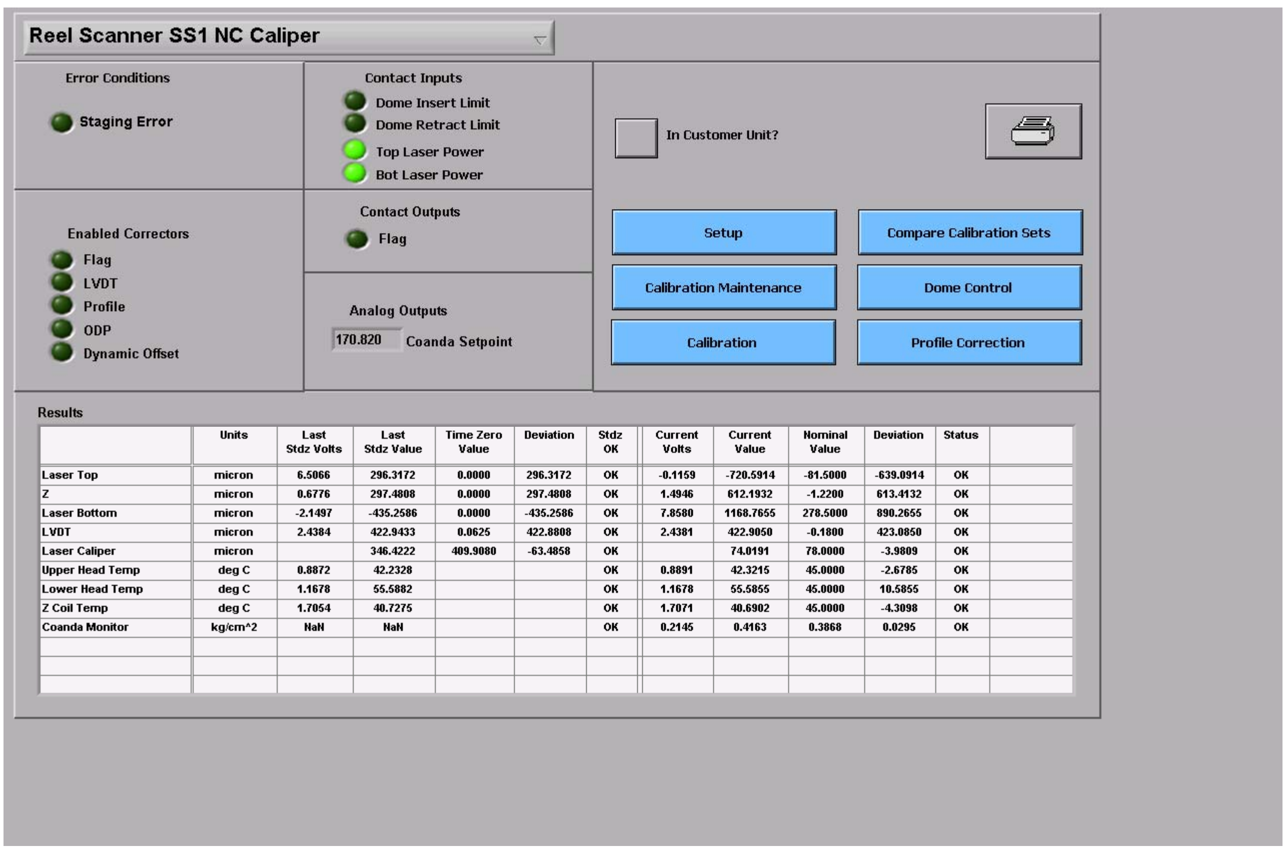

Figure 4-1 Laser caliper software display in Da Vinci

4.1. Laser caliper measurements

The laser caliper sensor has a number of measurements which can be selected as profiles these are:

NCC UH Laser Disp	ZML
NCC UH Z Disp	Z-sensor
NCC LH Laser Disp	CML
NCC LH LVDT Disp	LVDT
NC Caliper	Calculated caliper
NC Caliper (16SA)	Spatially averaged caliper.

The spatially averaged caliper is created from **NC Caliper** and is averaged with a 16 mm width to match the size of the contacting caliper and the size of the anvil specified in the TAPPI 411 standard. The spatially averaged measurement should be significantly less noisy than the **NC Caliper** measurement.

There are other measurements which are periodic. These are described in Table 1-3.

4.2. Setup display

The setup display allows input of various basic parameters for gauge operation. See Figure 4-2. This display is divided into various functional areas.

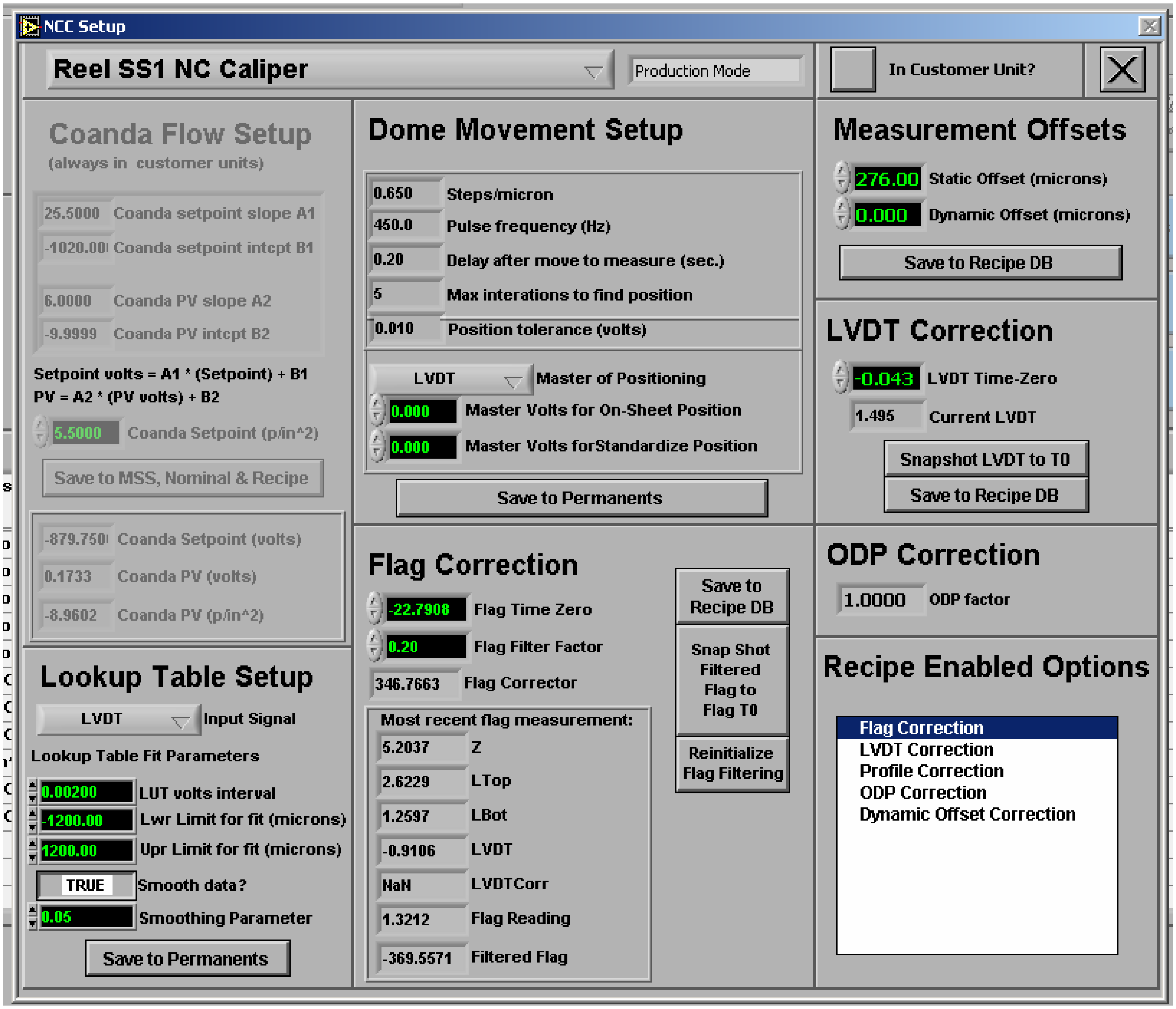

Figure 4-2 NCC Setup display

4.2.1. Coanda flow setup

The Coanda flow setup portion of this display is not currently used on this release of the gauge. The flow rate through the air clamp is manually adjustable only. The plenum pressure is measured electrically and is available on Da Vinci, but there is no electrically controlled valve.

4.2.2. Lookup table setup

The lookup table setup allows specification of some details in how the lookup tables stored in the RTDR are computed. As described in detail in Section 2.2, the lookup tables are used by Da Vinci because they are an efficient way to store the generally nonlinear signal-displacement relationships for the on-board measurement devices.

The first parameter allows specification of the granularity of the lookup table, in units of volts. An entry of 0.002 V is recommended.

In computing the lookup table, the computation fits a line to the signal/displacement relationship. The fields **Lwr Limit for fit** (microns) and **Upr limit for fit** (microns) indicate the displacement range over which the fit to determine the slope will be done. The default values of +1200 µm and -1200 µm are appropriate entries for the limits, for all devices, when the scanner head gap is at the 10 mm specification. The most common reason to deviate from the ±1200 µm default values for these parameters is when the scanner gap is wider than normal. In this situation, the calibration can include significant deadband. Figure 4-3 shows a case where the scanner gap is too large. The slope of the blue relationship is 189 µm —a value that would suggest a gauge problem. However, there is no hardware failure in this example, there is simply some deadband included in the fit. In this graph the linear portion of the calibration curve is approximately bounded between 400 µm and -1500 µm. Selecting these values as limits, it is possible to obtain a more sensible slope, closer to 150 µm /V.

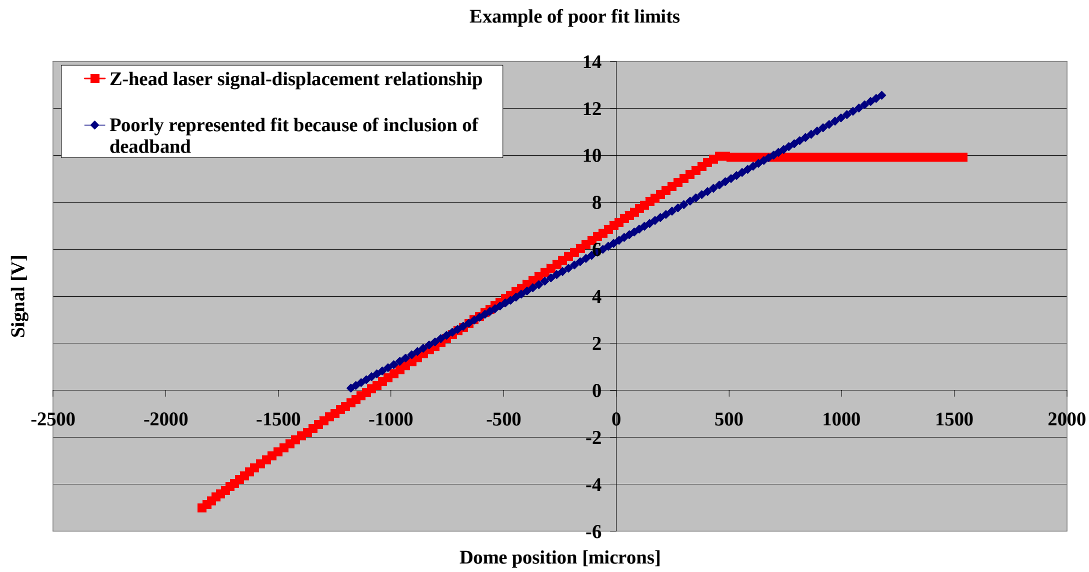

Figure 4-3 Example of misleading slope reported by Da Vinci due to deadband included in fit range

The smooth window button turns smoothing on and off when generating lookup tables. The smoothing parameter number (that is, 0.05) is a fraction of the entire range on either side of the smoothed point over which the smoothing occurs. Therefore, if the calibration occurs over 3 mm, the smoothing width for each point is 0.15 mm on each side of the smoothed point. A best fit using a fourth order polynomial is made to the point to be smoothed and the range on both sides. The moved point is then used for the LUT generation. Whether smoothing is employed or not, straight lines are fit between the points to generate the lookup tables.

4.2.3. Dome movement setup

This portion of the display permits selection of a **Master** for dome positioning and selection of the signal values corresponding to the desired dome positions for standardizing and onsheet. It is recommended that the **Master** sensor for onsheet positioning remain the LVDT.

See Section 2.1 for a description of how to physically select the appropriate position of the dome for onsheet measurement. Once the physical position is selected, be sure that it is the signal level, in volts—not the displacement value—that is entered into the dome movement setup display.

In most cases the standardize volts should be set to be the same as the onsheet volts. However, in some cases the dome must be placed so if the same position were used for standardizing one or more of the sensor readings would be out of range. If this is the case then set the **Master Volts for Standardize Position** to be closer to 0 V.

4.2.4. Flag correction

The flag correction is intended to correct the reported absolute caliper value. This is done by assuming that the caliper of the internal flag is constant in time and measuring the flag thickness at standardize. Any drift in the value of the flag thickness is exclusively attributed to gauge measurement drift.

The basic relationship of Equation 1-1 can be written to include the corrector as:

$$t_{NCC}(x) = Z_Z(x) - Z_{ZML}(x) - Z_{CML}(x) + \Delta t_o + \Delta f,$$

Equation 4-1 Caliper relationship with flag corrector active

where Δf is the flag corrector. The flag corrector accounts for the perceived change in flag thickness over time of the flag. Specifically, $\Delta f = f_{t_0} - f_{now}$ f_{now} is the most recent filtered flag value and f_{to} is the flag value at some time zero. Both these flag thicknesses use Equation 1-1 to determine the flag caliper at standardization.

Time zero can be redefined at any time by pressing the **Snap Shot Filtered Flag to T0** button.

This corrector, *Δf*, is added to the basic caliper expression. If, for example, the flag reads thicker at a moment in time, the gauge is over-reporting its caliper reading and has to have its measurements reduced by the same amount.

4.2.5. Measurement offsets

The measurement offsets have been implied in the expressions for the caliper computation this far. The static offset, Δt_o, and dynamic offsets, $\Delta t_o'$ are merely scalar constants that will be added to the computed caliper so that the absolute value of the computation is sensible. The expression for caliper becomes:

$$t_{NCC}(x) = Z_Z(x) - Z_{ZHL}(x) - Z_{CHL}(x) + \Delta t_o + \Delta t_o^{'}.$$

Equation 4-2 Caliper relationship with flag corrector active

The static offset is a grade independent variable whereas the dynamic offset is a variable which may be entered into grade recipes. This value may change due to surface effects such as gloss or coating. The static offset will have to be adjusted after calibrations.

4.2.6. LVDT correction

The LVDT correction is intended to correct the reported absolute caliper value, in particular because of thermal breathing of the gauge. Review Figure 1-2 to identify that any thermal expansion of the calibration head can lead to an error in measurement. This is done by subtracting away any excursion, from some time zero value, of the LVDT reading. Drift in the value of the LVDT displacement likely indicates thermal breathing of the gauge.

The basic relationship of Equation 1-1 can be written to include the LVDT corrector as:

$$t_{NCC}(x) = (Z_Z(x) + \Delta Z_{LVDT}(x)) - (Z_{ZHL}(x) + Z_{CHL}(x)) + \Delta t_o,$$

Equation 4-3 Caliper relationship with LVDT corrector active.

where $\Delta Z_{LVDT}(x)$ is the LVDT corrector function. The LVDT corrector accounts for the perceived change in gauge geometry over time. Specifically, $\Delta Z_{LVDT}(x) = Z_{LVDT\,t_0} - \Delta Z_{LVDT}(x)_{now}$. $\Delta Z_{LVDT}(x)_{now}$ is the most recent filtered LVDT profile value and ΔZ_{LVDTto} is the LVDT profile value at some time zero.

Time zero can be redefined at any time by pressing the **Snap Shot Filtered LVDT to T0** button.

4.2.7. ODP correction

The optical depth of penetration (OPD) effect is one in which the sensitivity of laser gauges differs from the calibration sensitivity for certain grades. The corrective effect is to inflate or deflate the calculated profile.

$$t_{ODP}(x) = \overline{t_{measured}(x)} + (t_{measured} - \overline{t_{measured}(x)}) * ODP,$$

Equation 4-4 ODP calculation.

where the overbar denotes the profile average and ODP is the value of the corrector.

4.2.8. Recipe enabled options

This menu allows you to determine which, if any, correctors are being used to report the NCC measurement. The correctors can be turned on and off with a double-click. However these settings will be lost on recipe change. Permanent changes should be set on the **recipe maintenance** display in the **NCCalPxx configuration table**.

4.3. Calibration maintenance display

The calibration maintenance display is useful for implementing calibrations for production measurement. It is not possible to have the gauge physically perform a calibration operation from this display, only work with calibrations previously saved to disk. It is possible to manipulate the working calibrations while the sensor is in production mode. Be aware that this will yield discrete step changes in measurement. The most common application of the calibration maintenance display is to apply a previously saved calibration (saved from the **Calibration** display, not the **Calibration Maintenance** display) to the RTDR for measurement. Usually, this is done immediately following the performance of a physical calibration operation and a consequent saving to disk file of the raw calibration data. It is not possible to enter calibrations into the working values through the **Calibration** display. In that display it is possible only to save a calibration to the current recipe, after which it would be required to reload the recipe if seeking to use the most recent calibration for measurement. This is undesirable because reloading the recipe may overwrite parameters associated with other sensors (moisture, weight and color targets, for example) that have been manually adjusted by mill operators. The calibration maintenance display allows entry of the unique NCC calibrations to the working storage of the RTDR and to recipes without influencing parameters associated with other sensors.

Another use of the **Calibration Maintenance** display is to confirm what calibration parameters are currently being used. Da Vinci employs a LUT to internally represent the signal/displacement relationship for all four measurement devices on the NCC gauge. The precise format of the LUT is a single column ASCII text file with entries defined in Table 2-1. A device LUT can contain up to 20001 individual entries and Da Vinci does not present the entire LUT on this display. Only the slope and intercept of the signal/displacement relationships are presented. The offset, in units of microns, is presented by the calibration constant A0. The slope, in units of microns per volt, appears as the calibration constant A1.

Toggle the signal drop-down menu to inspect the slopes and offsets of the LUT currently being used for a specific device. As well, the consequences on measurement of changing the LUT can be previewed on this display before the actual update is done. For whatever device is selected under **Signal**, the display will display the signal profile of the device, in volts, the displacement profile, in units of microns, and the consequent caliper reading. This display is useful to assess if any profile errors are a consequence of outdated calibrations.

Figure 4-4 illustrates the Calibration Maintenance Display. This display is used to import and generate device lookup tables and inspect the effects of calibrations before they are stored to working and recipe memory.

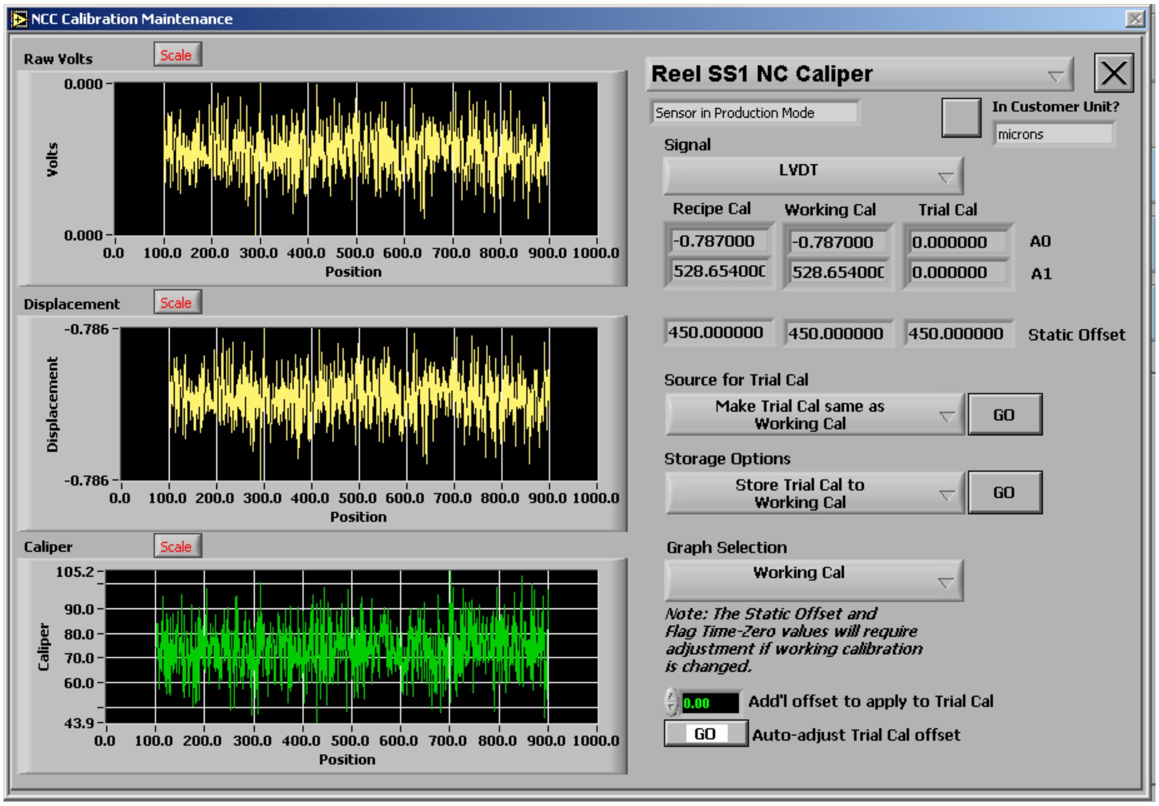

Figure 4-4 NCC Calibration Maintenance Display

Select any of the four devices to update their RTDR calibration values. Only the direct devices have their calibrations updated in this display. In the event that an LVDT is replaced at site, it would arrive with a renewed calibration LUT from the factory and this LUT would be entered into Da Vinci. This is the only case where it is expected that the LVDT calibration parameters are manipulated. If an LVDT replacement does occur and its LVDT LUT needs to be refreshed:

1. Copy the LUT file delivered with the LVDT to the Da Vinci server into the directory *Honeywell/Database/Calibration Data/NC Caliper*.

2. Select **LVDT** as the signal and choose the **Read Trial Cal from Disk File** from the **Source for Trial Cal** drop-down menu. See Figure 4-5.

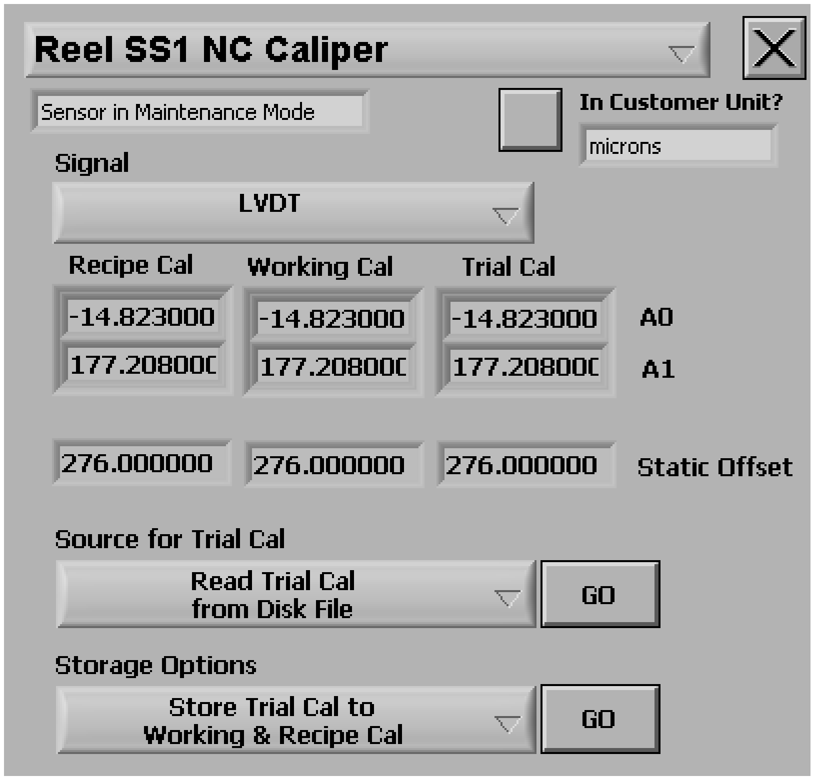

Figure 4-5 Entering a LUT for LVDT

3. In the **Trial Cal** column, new A0 and A1 appear as the contents of the text file are read into the RTDR. At this point, the calibration is not yet active, it is merely a trial for review.

4. If the LUT is considered valid (this can be judged by inspection of A0 and A1), in **Storage Options** select the appropriate storage locations, typically **Store Trial Cal to Working & Recipe Cal**. Be aware that an LUT stored only to Working will be overwritten by the contents of the recipe, should the grade be reloaded.

In principle, it is possible to directly load an LUT, in the form of a single column text file, for any of the direct devices. While possible, such an operation is improbable. To load a calibration for the Z-sensor, the Z-module laser or the cal-module laser, follow the details that follow:

1. Put the scanner in maintenance mode. This will ensure that the calibration update will apply to all grades. Return to the calibration maintenance page.

2. Select the signal for the calibration update (After a calibration has been performed, the operations to load individual device

calibrations into the RTDR have to be repeated for each direct device. The reason for this is so that if only a single device is thought be needing updating, this can be done for that device without forcing an update for the rest).

3. Under **Source for trial cal,** select **Generate Trial Cal from Raw Data File**. The dialog box shown in Figure 4-6 appears.

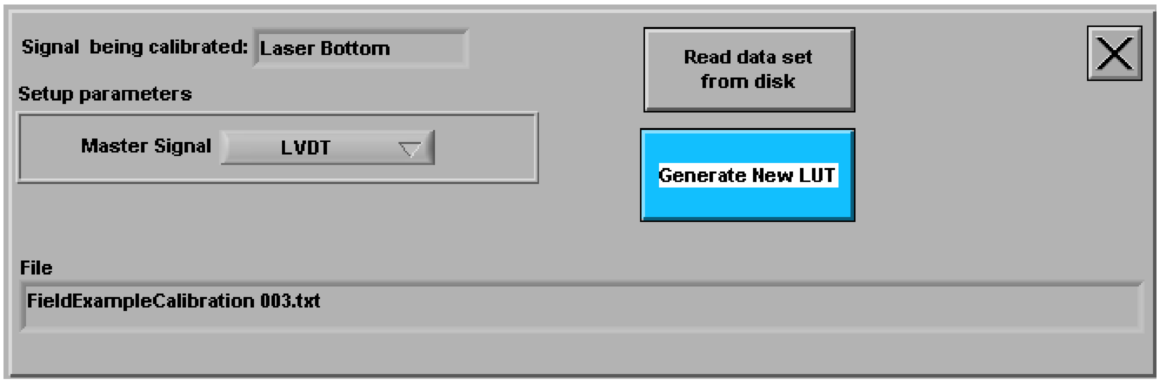

Figure 4-6 Selects raw calibration data file to generate an LUT

4. Selecting **Read data set from disk** opens a dialog box from which raw calibration files can be identified. The selected file appears in the **File** field.

5. Press **Generate New LUT**. A graph appears similar to the one in Figure 4-7. The graph expresses the nonlinearity of the device, not the error, as it is labeled. If the nonlinearity is very large, adjust the limits for the calibration fit (See Subsection 4.2.2).

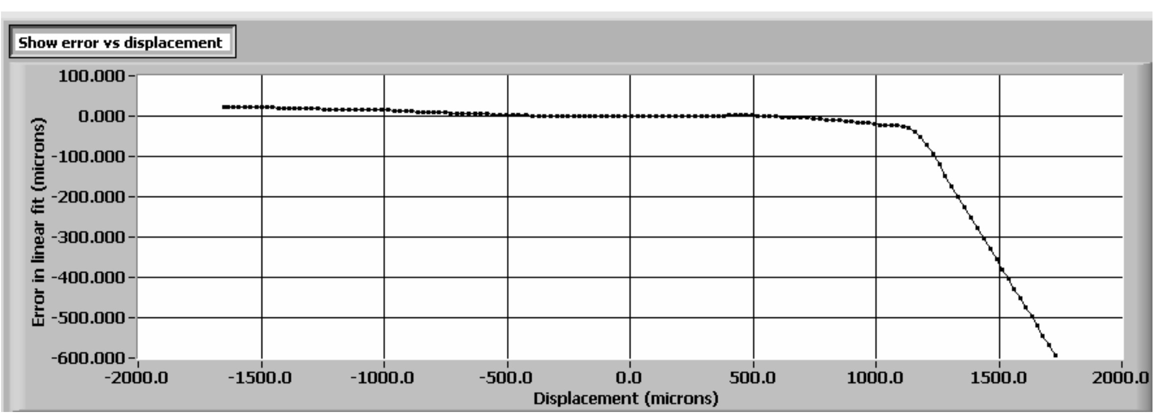

Figure 4-7 Graph of LUT nonlinearity generated from raw calibration data file

6. In the **Trial Cal** fields in the upper right corner of the display, the A0 and A1 constants are updated. To accept these constants for measurement, in **Storage Options** select the appropriate storage locations, typically **Store Trial Cal to Working & Recipe Cal**. Be aware that an LUT stored only to Working is overwritten by the contents of the recipe, should the grade be reloaded.

7. If storage to the recipe is included in the selection, a prompt appears to select which pointers should be associated with this LUT. Select the **apply to all** option as device calibrations are generally grade independent.

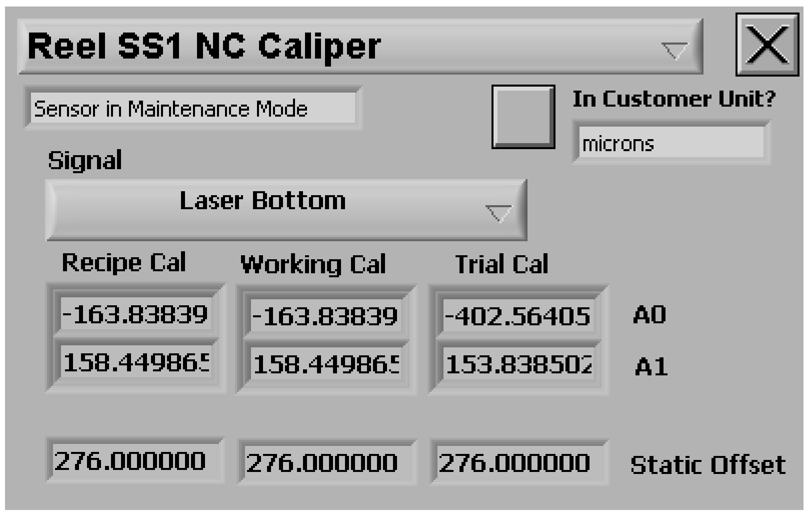

Figure 4-8 Entries updated in Trial Cal fields

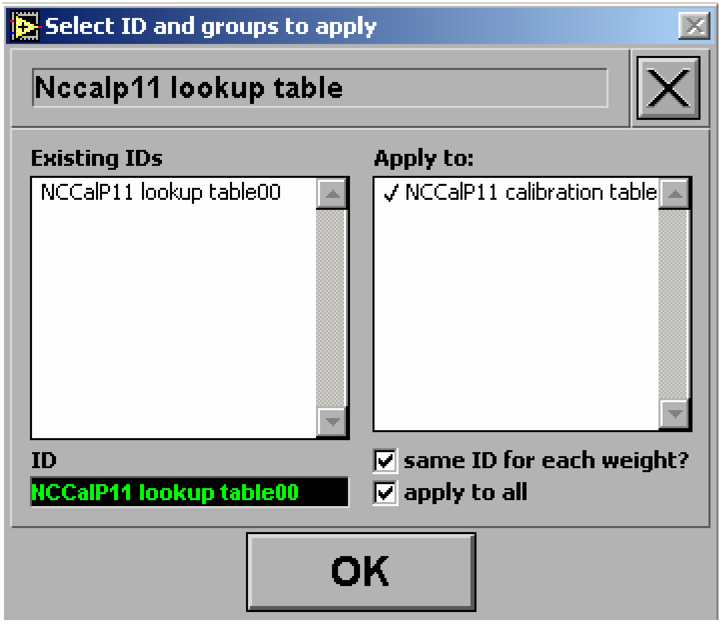

Figure 4-9 Select apply to all when associating LUTs with pointers

8. After the LUT have been entered into the recipe, the A0 and A1 parameter fields also reflect the update.

9. Perform steps 1-8 in maintenance mode and return the scanner to production mode. Verify that the proper A0 and A1 appear in both the **Recipe Cal** and **Working Cal** fields. **Working Cal** fields are what the sensor will use when it is making production measurements. If the working values are not the expect A0 and A1, perform steps 1-8 again, but this time in production mode. This will update the working values.

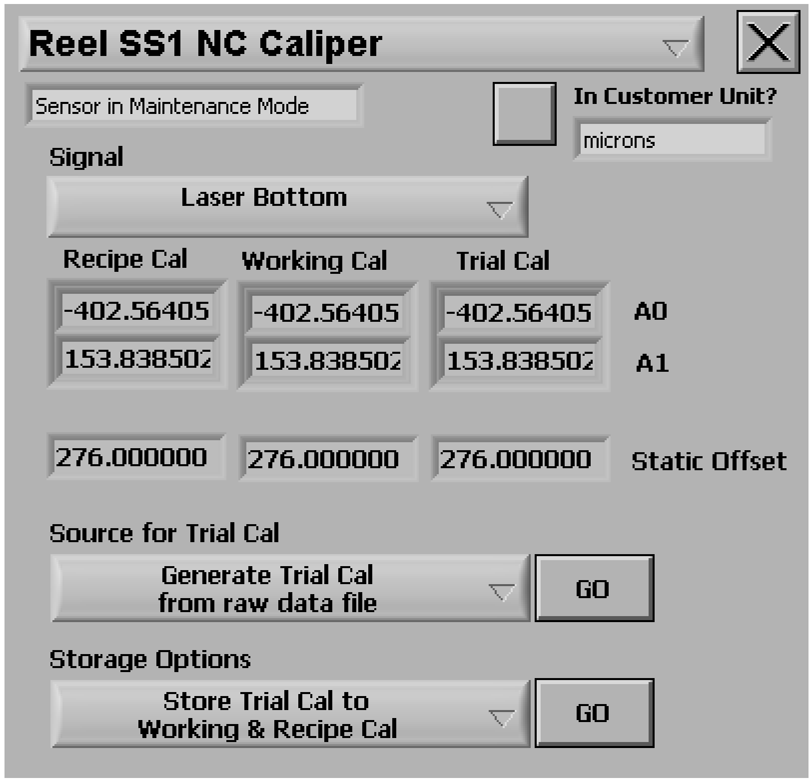

Figure 4-10 A0 and A1 updated after values stored to working and recipe calibrations

4.4. Calibration display

The **Calibration** display—not the **Calibration Maintenance** display—is intended to execute the physical calibration of the gauge. This section describes how to execute this process. Calibration activity must be performed in maintenance mode or the relevant displays and controls will be grayed out. Select **Calibration** from the NCC Display, Figure 4-1, and the **NCC Calibration** display appears. See Figure 4-11.

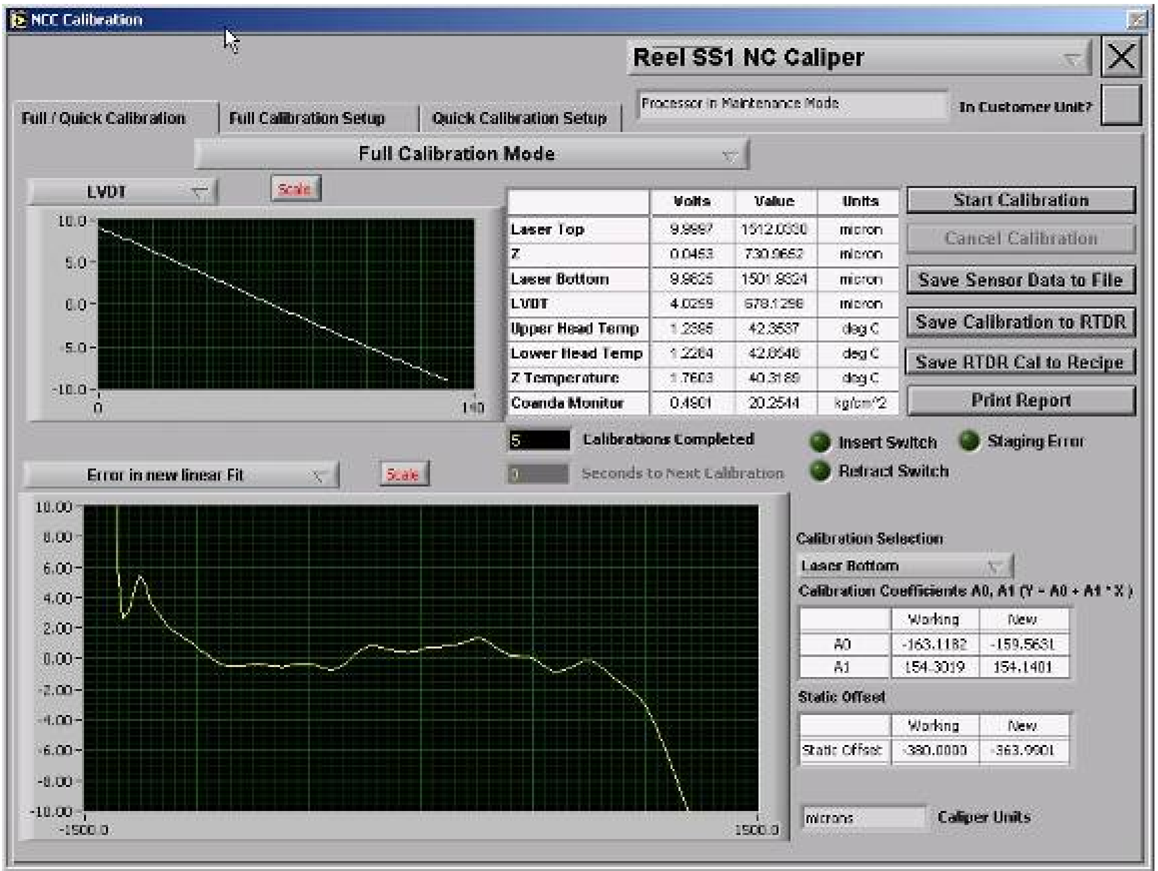

Figure 4-11 NCC calibration display

Some setup parameters are required before starting a calibration. Select the **Full calibration setup** tab to see a display as in Figure 4-12.

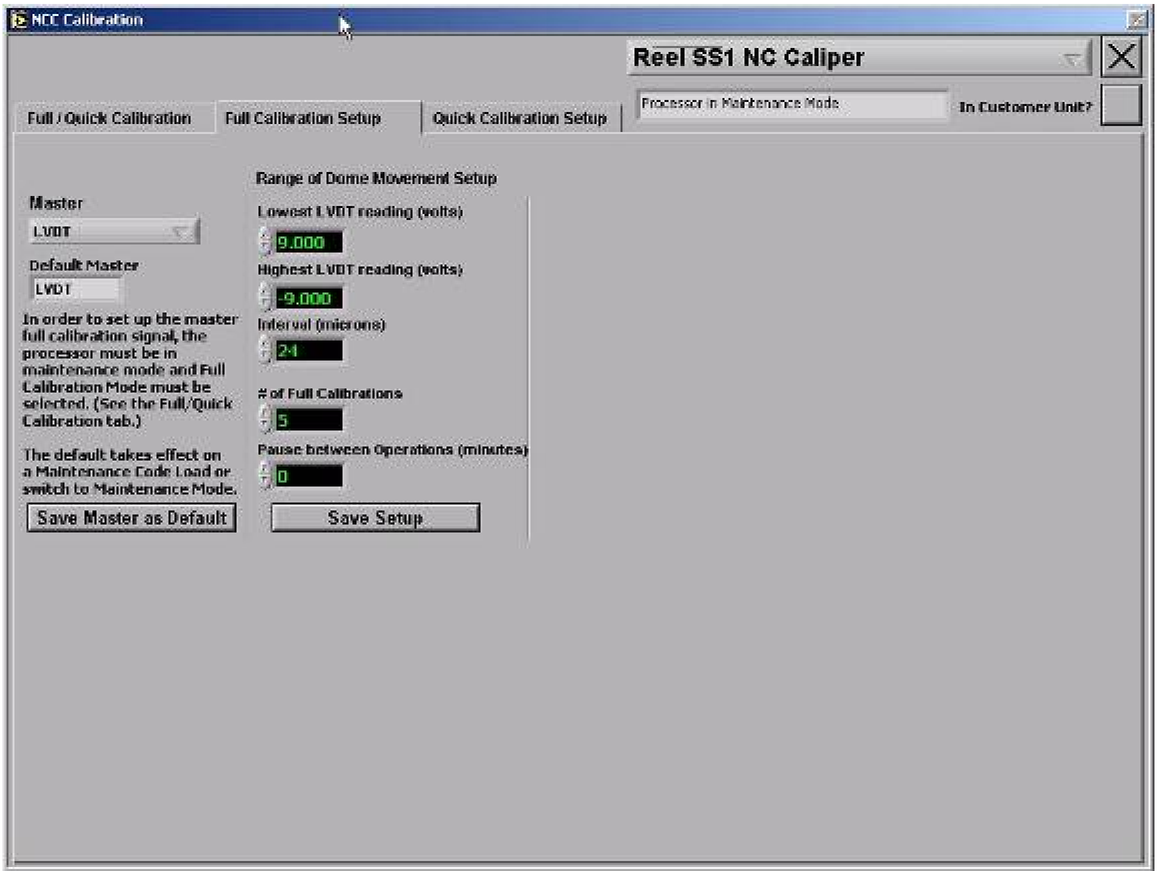

Figure 4-12 NCC calibration setup display

Some device must be used to determine the calibration limits, this is called the Master. The choice of Master defines what device is used to determine the upper and lower travel limits of the calibration module's target as it passes through the calibration range. These values are in units of volts, not displacement.

The master device is normally the LVDT, though it is possible to select the any of the direct devices to specify the calibration travel limits of the calibration module target. The limits on the LVDT indicate the signal level at the dome's lowest point to the highest point. This is normally a high voltage +9 V (dome retracted into the lower head) for example, to a low voltage, -9 V, (dome extended towards the upper head) for example. See Figure 2-1 for a schematic of expected physical positions and signal levels in the gauge.

The full signal range of the LVDT ±10 V covers slightly more than the 3-mm calibration range of the gauge. It is prudent to set the upper and lower limits just inside the ±10-V rails to prevent the gauge from attempting to find a position inside its dead-band. The displacement increment between calibration points is also user selectable. Twenty-five microns is a sensible value that will generate sufficient point density in the calibration without being unduly time consuming to execute.

The **# of full calibrations** field, when selected, has the system repeat the calibration several times. Da Vinci will sort the points so all the calibrations are overlaid before smoothing is done, and a lookup table is calculated. For this reason, a number of calibrations greater than one should only be selected if the heads are pinned and clamped. Once the setup is done, return to the **NCC calibration** display and select **Start calibration**. The gauge proceeds through the specified number of calibrations. The display appears as in Figure 4-13. The axes of the upper graph are: calibration step index is on the x-axis and device signal on the y-axis. The upper plot can show only the LVDT result when the calibration is in progress, once the calibration is complete, the displacement/signal relationship for any of the devices can be viewed.

A calibration takes a few minutes to execute. During the calibration, the small graph in the upper left hand corner displays the LVDT voltage against the step number. Track the progress with this display. If the voltage does not seem to change, stop the calibration and restart it. If the dome will not move, see Section 7.1. If a version of RAE is being run that is less than update 10, a **scanner down** alarm will appear during the calibration. If it is a problem a software patch can be obtained from Vancouver Engineering.

Details of the calibration can be viewed on this display for purposes of determining the validity of the calibration. The lower plot shows the nonlinearity of the device signal/displacement relationship. There are three choices available on this drop-down menu:

- **Error in new linear fit** plots the specific device's nonlinearity in units of displacement against absolute displacement as given by the LVDT.
- **Lookup table correctors** plots the signal increment, in volts, which will be added to the measured signal so that the sum of these signals can by multiplied by the best fit slope to obtain the device displacement, recall the last term in parentheses of Equation 2-2. The **Lookup table correctors** plot is simply scaled version of the **Error in new linear fit** plot, with the best fit slope being the scale factor.

- **Difference of new & working** allows comparison of the values of the displacement nonlinearities between the most recently completed calibration and the current working calibration.

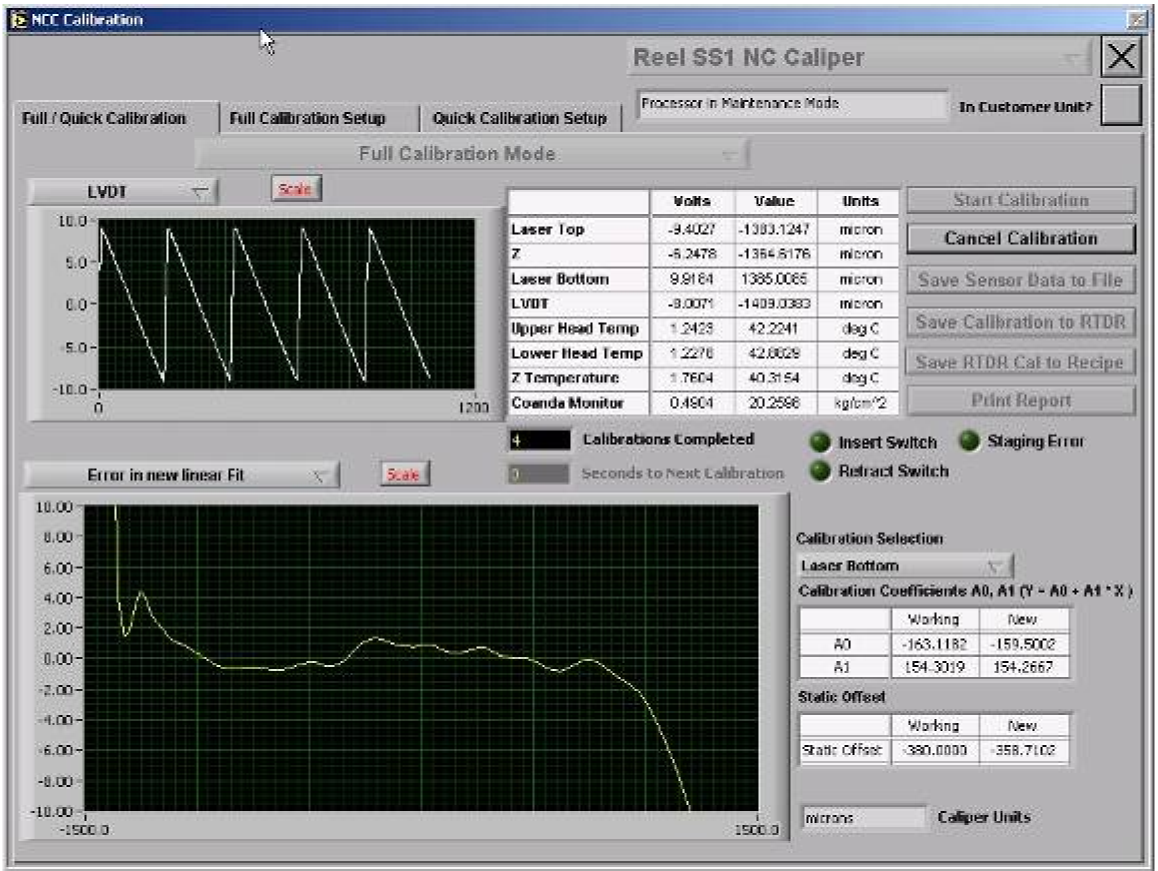

Figure 4-13 Calibration in progress

The slope, A1, and offset, A0, of the most recently generated LUT are displayed in the **New** field. These can be immediately compared to the current working values on the display. If the user deems the calibration to be valid, the user has the opportunity to renew the calibration being used for measurement. The **NCC Calibration** display offers several choices as to how to store and enter calibrations for measurement. It is possible that a calibration can be entered into the recipe—but not the working field of the RTDR—from this display. A reloading of the entire recipe, (with potential unwanted impact on other non-NCC parameters) would then be required if this display is used to save the calibration to the recipe.

When the calibration is complete and determined to be good, enter it into the RTDR and the recipe by following the details described in Section 4.3 once the raw calibration file has been saved to disk from the **NCC**

Calibration display. To save a raw calibration file to disk, press **Save Sensor Data to File** and name the file and save it in the dialog box that appears. It is recommended that print out copies of the calibrations. If all the steps are not followed properly when entering the calibration to the recipe then a calibration can be temporarily lost. In order to print out the calibrations, select each device in turn with the **Calibration Selection** drop-down menu and press **Print Report**.

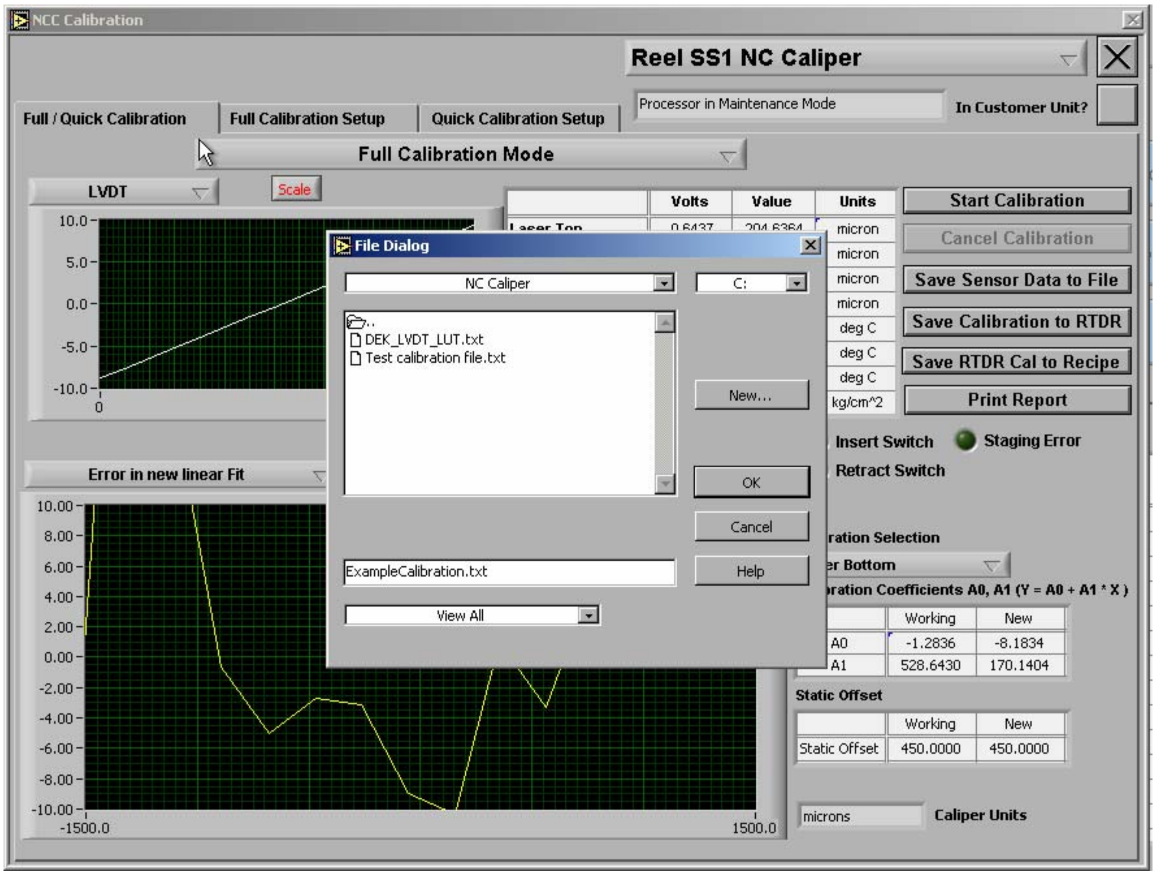

Figure 4-14: Saving sensor calibration data to file.

The raw calibration data file is an ASCII text file delimited by tab characters. The first line of the file is reserved for an optional comment, otherwise, the rows of the raw calibration file indicate individual points of the calibration.

Don't enter working calibrations through the **Calibration** display. Remain in maintenance mode and follow the steps outlined in Section 4.3 to update the working calibration entries.

This calibration routine creates text files from which the look-up tables are generated. The first line is a text header followed by the displacement and voltage data. To analyze these files it is necessary to know the column identifications. Table 4-1 shows the column identifications.

Table 4-1 Calibration file column identification

A	B	C	D	E	F	G	H
ZML Volts	ZML previous displacement	Z Volts	Z previous displacement	CML Volts	CML previous displacement	LVDT Volts	LVDT Displacement

Columns B, D, and F are the displacements generated from the in-memory LUT.

4.5. Compare calibration sets display

This section can be used to import and view calibration sets stored in test files. Use this tool only if there is a suspected nonlinearity of a specific measurement device changing in time.

4.6. Dome control setup display

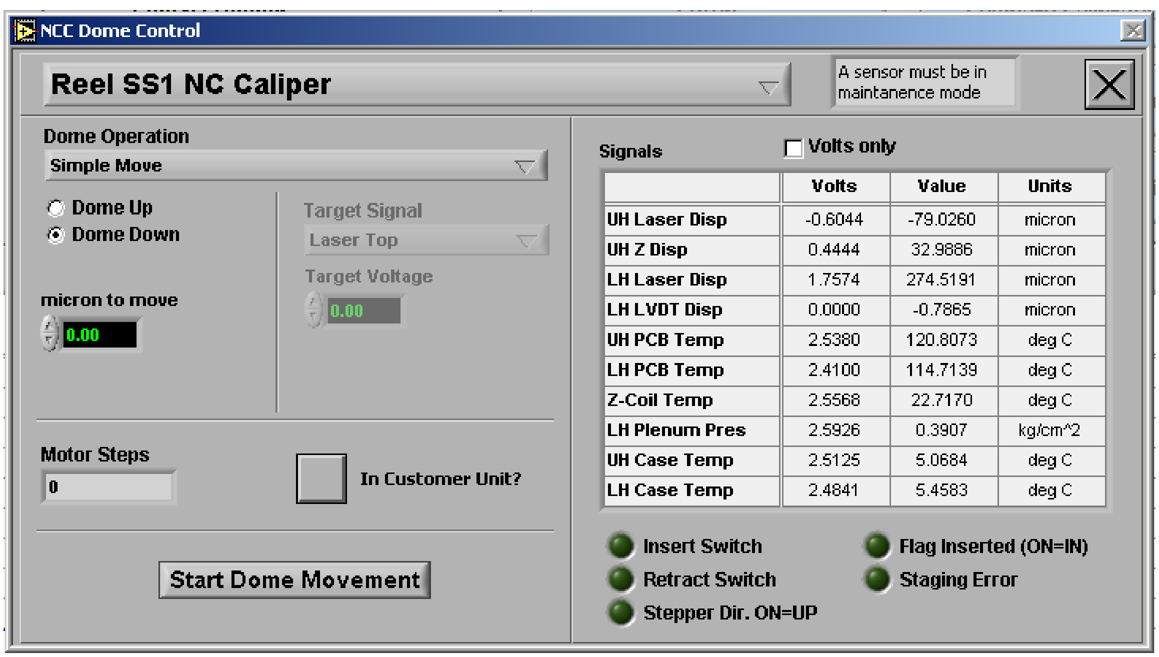

Figure 4-15 NCC Dome control display

The dome control display allows basic moves with the dome. Use this display in maintenance mode. By choosing different modes from the **Dome Operation** drop-down menu, you can make discreet up and down moves by a specified number of microns, seek a dome position that corresponds to a specific measurement device voltage, or you can force the dome to move to the onsheet position or retract to the home position.

4.7. Profile Correction display

Profile correction for the laser caliper can be quite different than for other sensors. The other sensors that employ profile correction build their correction profiles while scanning on a flag or a known-good sample. The lasers used in the laser caliper have small spot sizes (~0.5-mm diameter) and the flag and most samples are not flat to <1 µm on this scale. When scanning, the scanner heads move with respect to each other. The profile measured when scanning on the flag will be a map of the caliper non-uniformity as a function of the scanner CD and MD misalignments. Profile correction, for laser caliper, corrects for persistent tension profiles on the paper machine that distort the sheet shape at the measurement position. The best source for a true profile is a contacting caliper. It may be possible to use very good lab measurements as well but this has not been attempted and cannot be recommended at this time.

The profile correction display cannot be used by itself to generate correction profiles. The reason is that separate profiles are generated in the forward and reverse directions. Since the contacting caliper does not measure to the edge of the sheet while coming onsheet there will be a portion missing from the portion of the correction profiles when coming on sheet in both the forward and reverse directions. The profile correction algorithms cannot be easily modified to use the trued now profiles instead of the last scans.

It is best to build profile corrections offline and then import the data. This can only be done by collecting profiles with the color map utility or the datalogger. The profiles must be built with a program such as Microsoft Excel or Matlab. The profile correction display can then be used to import the data. Obviously this should only be done by those who have a good working knowledge of Da Vinci. One hint is that the profile correction display uses the scanner position. Many systems reverse the positions to match actuator positions this must be taken into account as the remapped positions are the ones collected by the datalogger or the color map. A second hint is that the profile correction display can be used to generate an example file which can be used to get the correct format for the profile correction files. The following instructions shall assume that trial profile corrections have been generated externally and must be imported with the **profile correction** display.

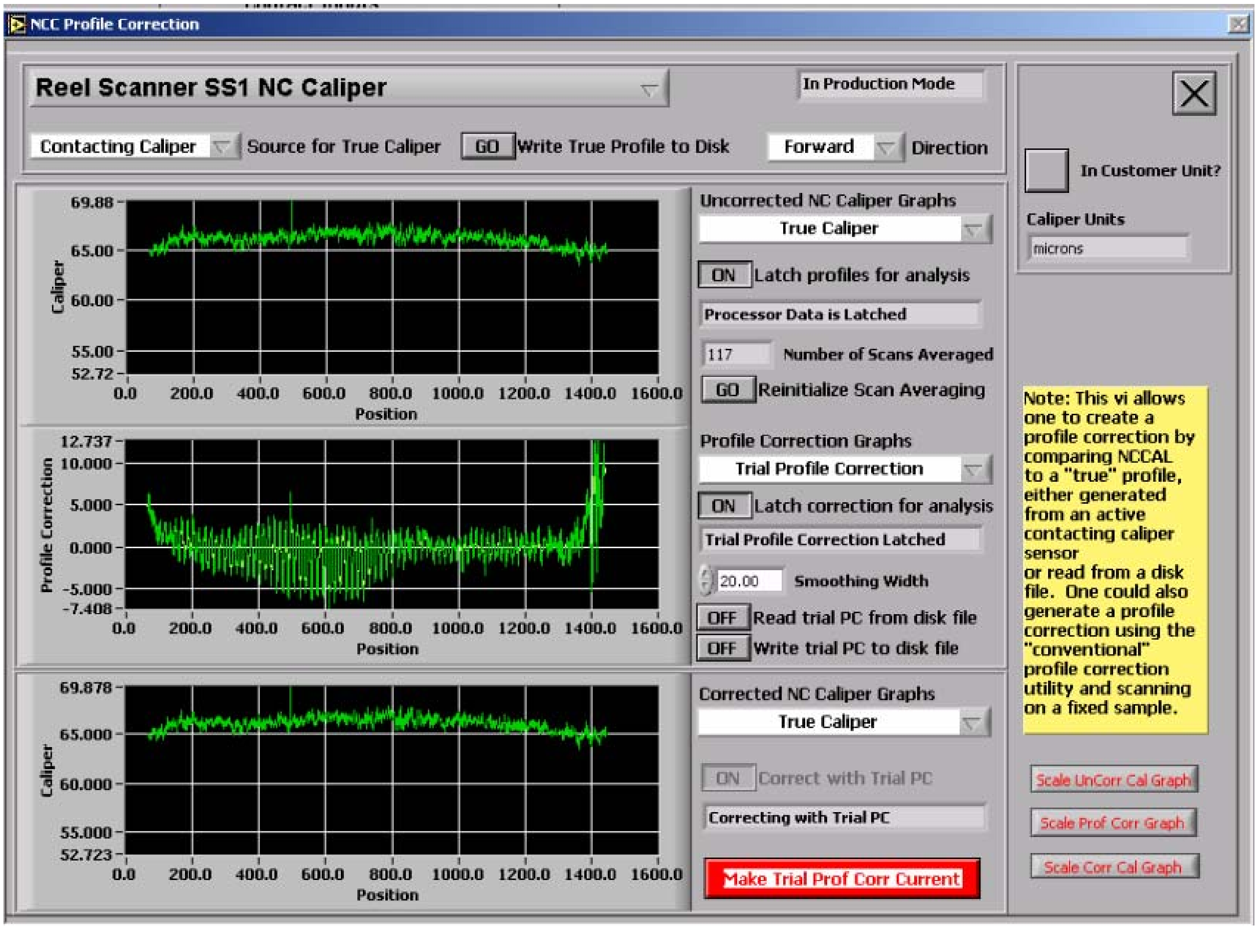

Figure 4-16 NCC Profile correction display

1. Select the **forward** or **reverse direction**. A separate profile correction is required for each.

2. Select **latch correction for analysis.** This makes the **Read trial PC from disk file** button visible.

3. Read the trial PC from the disk in directory *Honeywell/Database/Profile Correction Data/NC Caliper*. This must be a text file. As mentioned previously a trial PC can first be written to disk in order to determine the correct format.

4. Apply a smoothing width if desired. The smoothing can be done externally as well.

4.8. Sensor setup

There are a few settings to be optimized or checked before using the laser caliper in a production environment. These are listed in Table 4-2. It also serves as a table of default values.

Table 4-2 Da Vinci setup settings

Setting	Display	Value	Comments
Beam Half Width mm Upper Head Laser	**MSS Setup Diagnostics > MSS Job Set IO Setup**	50	Can try smaller values. Look for edge problems.
Beam Half Width mm Upper Z Gap		0	Measurement good through edge
Beam Half Width mm Upper Head Z Temperature		0	
Beam Half Width mm Upper Head Temperature		0	
Beam Half Width mm Lower Head Laser		50	Can try smaller values. Look for edge problems.
Beam Half Width mm Lower Head LVDT Gap		0	
Beam Half Width mm Lower Head Coanda Monitor		0	
Perf Module > X Axis		Same as for LCal	Want to set to be the same as LCAL if correlating signals. Presume that no other sensors use X and Y.
Perf Module > X Axis			
Phase Setup > Bkgd phases Phase Setup > Support Sensor Monitor> Bkgd phases	**Sensor Maintenance**	0	Laser caliper does not use a background phase. If one is requested an error will be produced.

Setting	Display	Value	Comments
Phase Setup > Check Limits, offsheet when bad, check drift limit **Phase Setup > Support Sensor Monitor> Check Limits, offsheet when bad, check drift limit**	**Sensor Maintenance**	Unchecked	At least during sensor set up these should remain unchecked to avoid problems. Once the sensor has been running stably for a period of time, it may be acceptable to check limits for the laser temperatures. It is unlikely that these temperatures would be driven too high by the temperature control circuit.

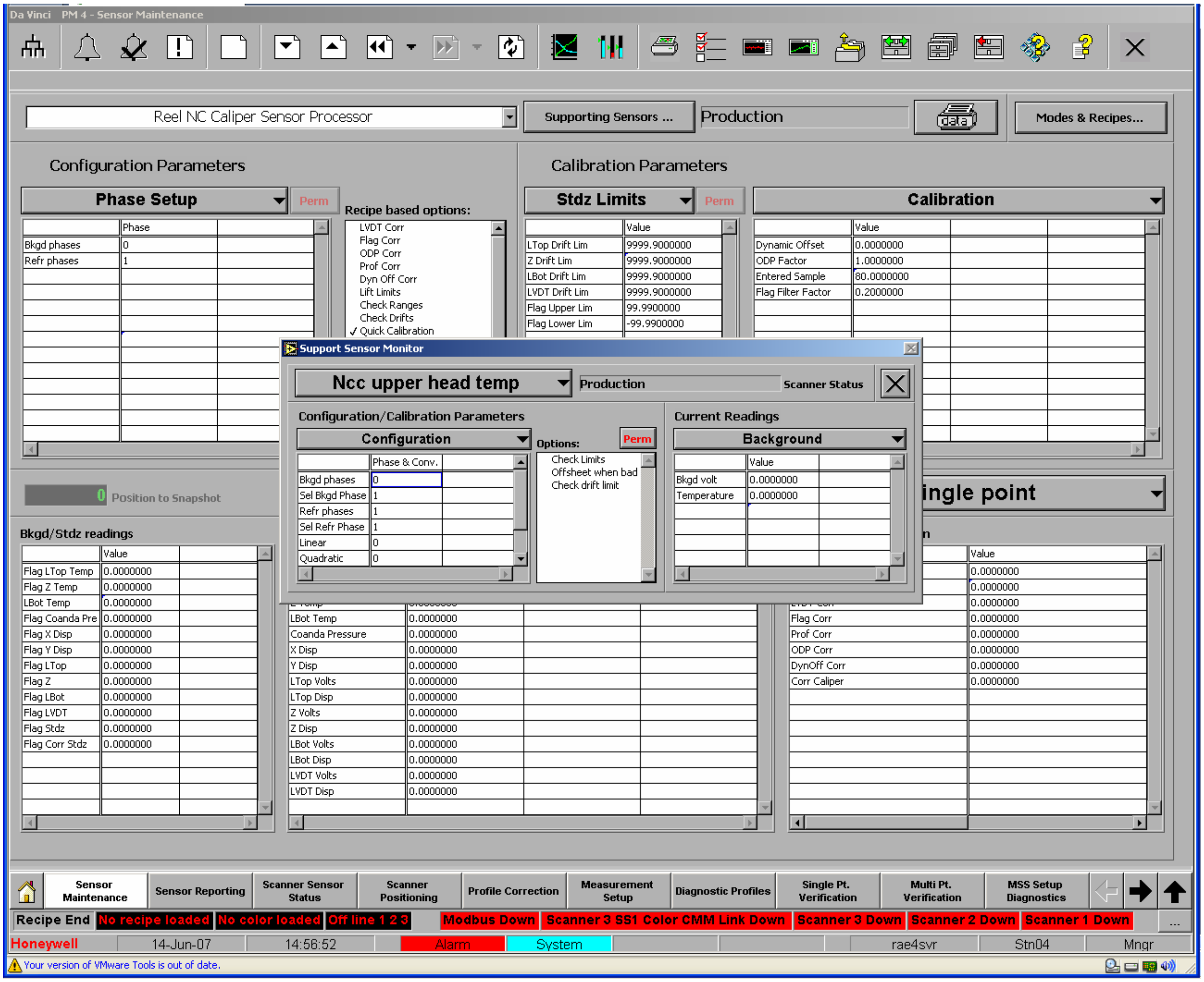

Figure 4-17 Example location of Bkgd phase and Check limits flags for laser caliper

5. Calibration

5.1. Calibration overview

While the Da Vinci calibration screens are described in Section 4.3 and Section 4.4 and calibrations are mentioned in Subsection 3.2.2.2, the calibration procedure is complicated and important enough that a separate chapter is necessary for clarity.

To calibrate the sensor, the stainless steel dome is stepped through the measurement ranges of the laser displacement sensors and the z sensor. The signals are measured with reference to the LVDT voltage. A calibration file is generated. It consists of the voltages from each device, the displacement of the LVDT calculated from the lookup table, and the displacements of each device calculated from the lookup tables currently in working memory. This procedure is initiated from the **NCC Calibration** display.

The calibration can be used by Da Vinci only after the calibration table is converted to individual lookup tables for each device. This procedure can be initiated from the **NCC Calibration** display or the **NCC Calibration Maintenance** display.

Table 6-1 shows recommended initial settings for calibration followed by a recommended procedure for performing the calibration and generating lookup tables.

5.2. Calibration setup

Table 6-1 lists suggested parameters for calibrations. Generally the values indicated should be modified at each installation.

Table 5-1 Initial settings for calibrations and lookup table generation

Display	Selection		Value	Comments
NCC Setup	**Lookup Table Setup > Input Signal >** **LVDT** **Laser Top** **Z** **Laser Bot**	LUT volts interval	0.002	Each device must be selected individually. The settings do not automatically work on all devices.
		Lwr Limit for fit (microns)	-1200.00	
		Upr Limit for fit (microns)	1200.00	
		Smooth data ?	True	
		Smoothing Parameter	0.05	
NCC Calibration	**Full Calibration Setup**	Master	LVDT	
		Lowest LVDT reading (volts)	9.000	
		Highest LVDT reading (volts)	-9.000	
		Interval (microns)	24	
		# of Full Calibration	1	
		Pause between Operations (minutes)	0	

5.3. Calibration Procedure

The following steps comprise the recommended procedure for calibrating the laser caliper and generating the device look-up tables. In many instances it may be desirable to change this procedure to suit individual circumstances. To fully understand the options available consult Section 4.3 and Section 4.4.

1. If this is the first calibration on a new system ensure that the LVDT lookup table (LUT) is loaded into the system.

a. Navigate to the **NCC Calibration Maintenance** display (see Figure 4-4).

b. Ensure that the **Signal** drop-down menu displays **LVDT**.

c. Select **Read Trial Cal from Disk File** from the **Source for Trial Cal** drop-down menu.

d. Press the **GO** button and select the appropriate file. The LUT offset (**A0**) and slope (**A1**) is displayed in the **Trial Cal** boxes.

e. Select **Store Trial Cal to Working & Recipe Cal** from the **Storage Options** drop-down menu and press the **GO** button. The LVDT LUT is now in working memory and the recipe.

2. Enter Maintenance mode from the **Scanner/Sensor → Sensor Maintenance** tab.

3. Open the **NCC Calibration** display as described and illustrated in Section 4.4.

a. Select **Start calibration,** observe the calibration proceeding on the screen. When it is finished:

b. Select **Save Sensor Data to File** and save the file with an appropriate filename and header. This step only has to be done once for each calibration.

c. For each of the sensor devices in the **Calibration Selection** tab, press the **Print Report** button to print out a copy for future reference.

4. Exit Maintenance mode from the **Scanner/Sensor → Sensor Maintenance** tab.

5. Navigate to the **Calibration Maintenance** display.

6. Select a signal (such as **Laser Top**) from the **Signal** drop-down menu.

7. Select **Generate Trial Cal from raw data file** from the **Source for Trial Cal** drop-down menu and press the **GO** button.

8. Select the calibration file desired by pressing the **Read data set from disk** button. If this file has been used previously the filename will appear in the **File** line of the screen. If this is the case, the calibration data is already in memory and does not have to be re-selected.

9. Press the **Generate New LUT** button. The lookup table appears on the screen along with the smoothed (if that option was selected in the **Setup** screen) data used to generate the LUT. The **X** box in the upper right corner of the small window can be used to close the window.

10. Store the calibration to the working and recipe memory by selecting the **Store Trial Cal to Working & Recipe Cal** option from the **Storage Options** pull-down menu and pressing the **GO** button.

11. Repeat steps 6 to 10 for the other two devices (**Z and Laser Bot**).

The calibration and lookup tables are now properly updated.

6. Maintenance

6.1. Maintenance schedule

Task	Tools required	Frequency	Section in manual
Inspect standardize report for flag failure, laser problems, or temperature control problems. Save report.		weekly	6.3
Clean triangulation sensor windows	CML: Allen key (5/64”) Phillips screwdriver (#2) ZML: Allen keys (1/8”, 5/64”) Both: cotton-tipped swabs, clean isopropanol, laser viewing card (6581400002)	Every shutdown – more frequently if necessary.	6.4
Check calibration		Every shutdown	6.5
Clean under CML dome and ZML dust cover	CML: Phillips screwdriver (#2) ZML: Allen keys (1/8”) Both: laser viewing card (6581400002)	Every three months or as required	6.6
Clean air clamp slot	Feeler gauge	Every three months or as required	6.7
Check air tubes and purge air pressures		Every three months or as required	6.8
Check alignment	Laser Caliper alignment tool, 5/32” Allen key.	Every three months or as required	3.2.6.2
Check head-split interlock	Laser viewing card	Every six months	6.9

6.2. Safely splitting scanner heads when laser caliper installed

For most maintenance procedures the scanner heads must be split. While there is an interlock present some precautions should be taken to ensure that there is no danger.

WARNING! Do not look into the laser hole until it has been verified that there is no emission.

1. Turn off laser keyswitch on endbell and remove key. Check that the diode by the key turns off.
2. If the scanner has its radlights connected to the laser caliper then check that the radlight indicator turns off.
3. Split the scanner heads. Check to ensure that there is no red emission from the z-module laser when projected onto the laser card (do not look into the laser or use a mirror-like surface to observe the beam). Use the laser alignment card to ensure that there is no infrared laser emission from the cal-module laser. Observe the laser card from an observation point at the edge of the scanner platform and a few centimeters above (do not look at the hole from above). Hold the card at a 45° angle, with the sensitive area above the hole. Laser emission will appear as a spot of light within this area. If emission is observed put the heads back together, it is not safe to work on the split heads and TAC should be contacted for assistance.
4. If there was no emission observed in the previous step, it is safe to proceed with the maintenance procedures.

6.3. Inspecting standardize report

Inspect standardize reports weekly. The primary information that will be obtained is information on the flag operation, the thermal stability of the temperature controlled devices, and dirt build up. To look for long term drifts, multiple standardize reports are required. Print out and save reports or use the HMX SQL utility to export them.

Table 6-1 Expected standardize values and spreads based on 100 entry standardize report

Standardize report column	Expected value	Expected 2σ	Comments
CML (or ZML) Case Temp	(45±2)°C	1 °C	In old versions of Da Vinci (RAE 4 update 10 and below). The temperature reported in the standardize report is actually the PCBA temperature. The case temperature is not reported.
LH (or UH) PCBA Temp	(50±7)°C	3 °C	Not critical
Z Temp	(43±2)°C	0.2 °C	
L Top Volts	(-9 to +9) V	1 V	Look for spikes to 10 V. If only one device shows spikes suspect the laser; if both do, suspect the flag.
L Bot Volts	(-9 to +9) V	0.2 V	Look for spikes to 10 V. Ensure LVDT constant.
Flag	±1000 μm without dynamic offset enabled.	10 μm	Look for a long term drift. Drift > 15 μm can indicate that optics must be cleaned or recalibration necessary. Examine Z-ZML and CML + LVDT graphs to see which head is likely to be causing the problems.
Calculated Values			
Z-ZML			CML + LVDT should be much more stable than Z-ZML. The two quantities should follow each other.
CML+LVDT			

Table 6-1 outlines the important quantities in the standardize report. Additionally, it is quite useful to use an external spreadsheet to plot these values and calculate and plot a couple additional quantities such as Z-ZML and CML+LVDT[4].

Figure 6-2 is a plot of component device displacement showing good device performance. Since the flag is attached to the calibration module the calibration module quantities should be much more stable than the z-module quantities. LVDT and CML should follow each other (in opposite directions) and ZML and Z should also follow each other (in the same direction). Figure 6-2 is a plot of Z-ZML and CML+LVDT. These values follow each other. Figure 6-3 shows the evolution of the flag standardize values both with and without LVDT correction. Two times the standard deviation (2σ) of the flag values at standardize is less than 10 µm. If this is not the case, examine the quantities plotted in Figure 6-2 to determine where the problem lies. The most likely explanation is that the windows need cleaning. Dirt buildup generally appears as a constant drift of the laser signals which carry through to a flag thickness drift (see Section 6.4). A variable (as opposed to a stable or drifting) flag reading may indicate that the flag is not returning the same position every time.

Of the temperature signals, the most important is the z-sensor temperature. The z-coil should be well regulated to 2σ = 0.2ºC. Variation larger than this will lead to measurement errors. The case temperatures are also regulated. In older versions of Da Vinci, the value reported is the interface PCBA temperature rather than the case temperature. When this problem is corrected the PCBA and the case temperatures will be recorded. The regulation of the case temperature should be to within 1ºC on a 2-σ basis.

See Chapter 7 if there are any suspected problems with any items on the standardize report.

[4] Vancouver Engineering can provide a suitable template with automated calculation and graphic if desired.

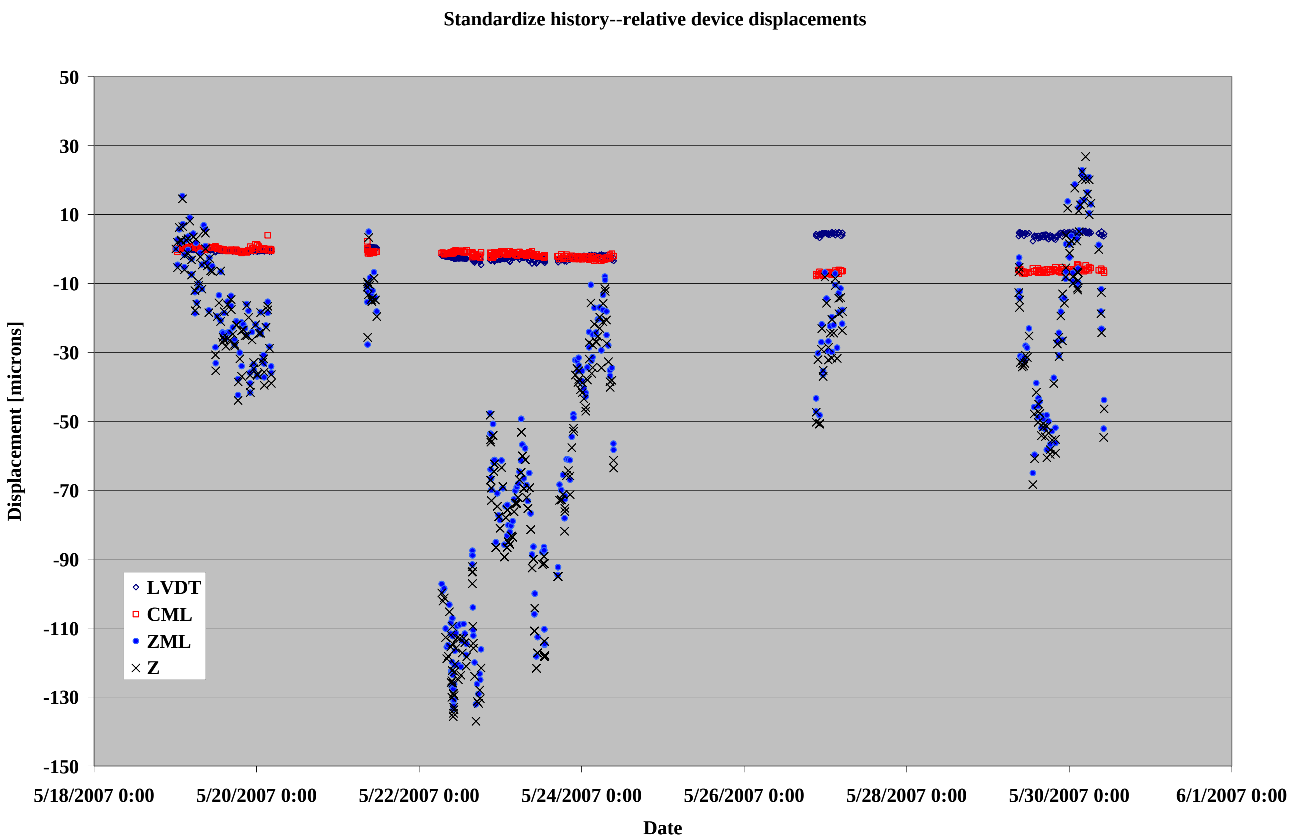

Figure 6-1 Example standardize displacements over time

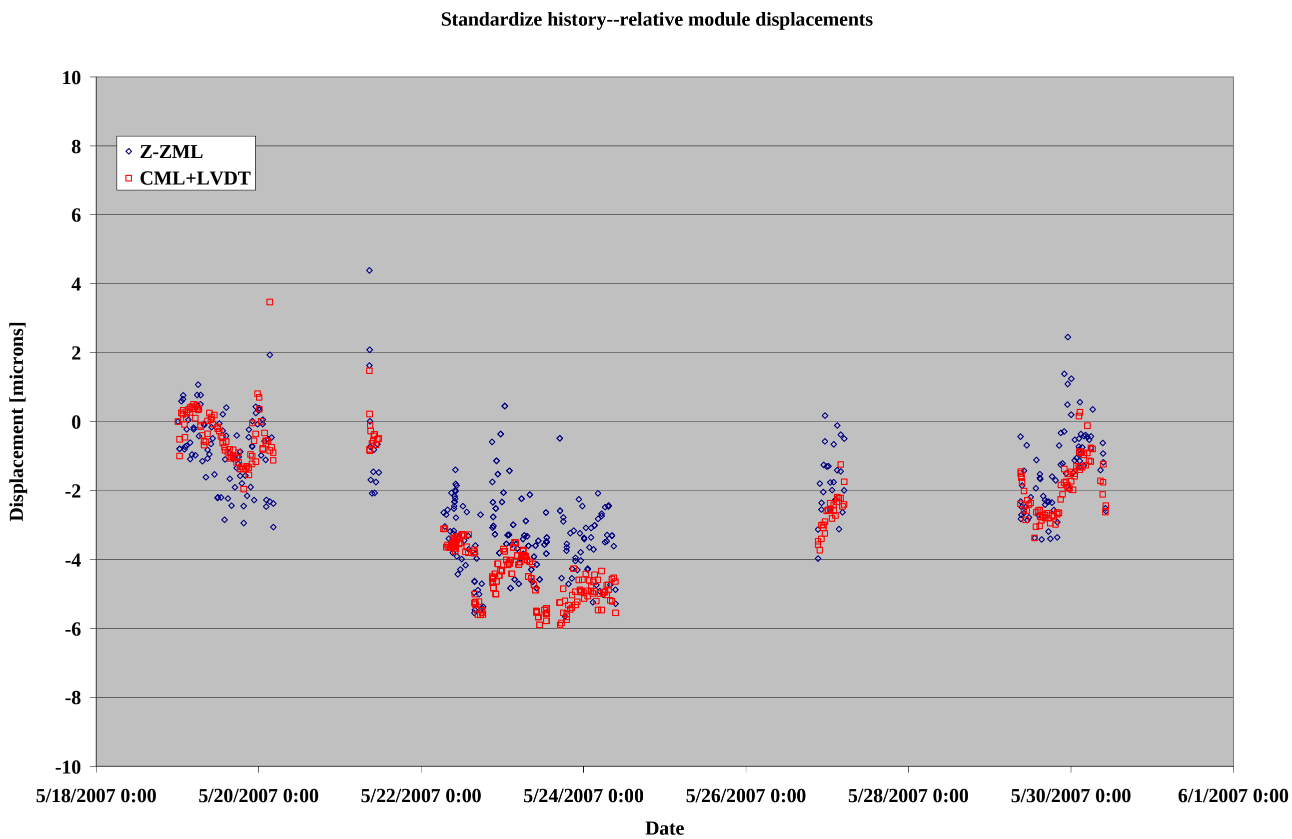

Figure 6-2 Example chart of calculated standardize quantities over time

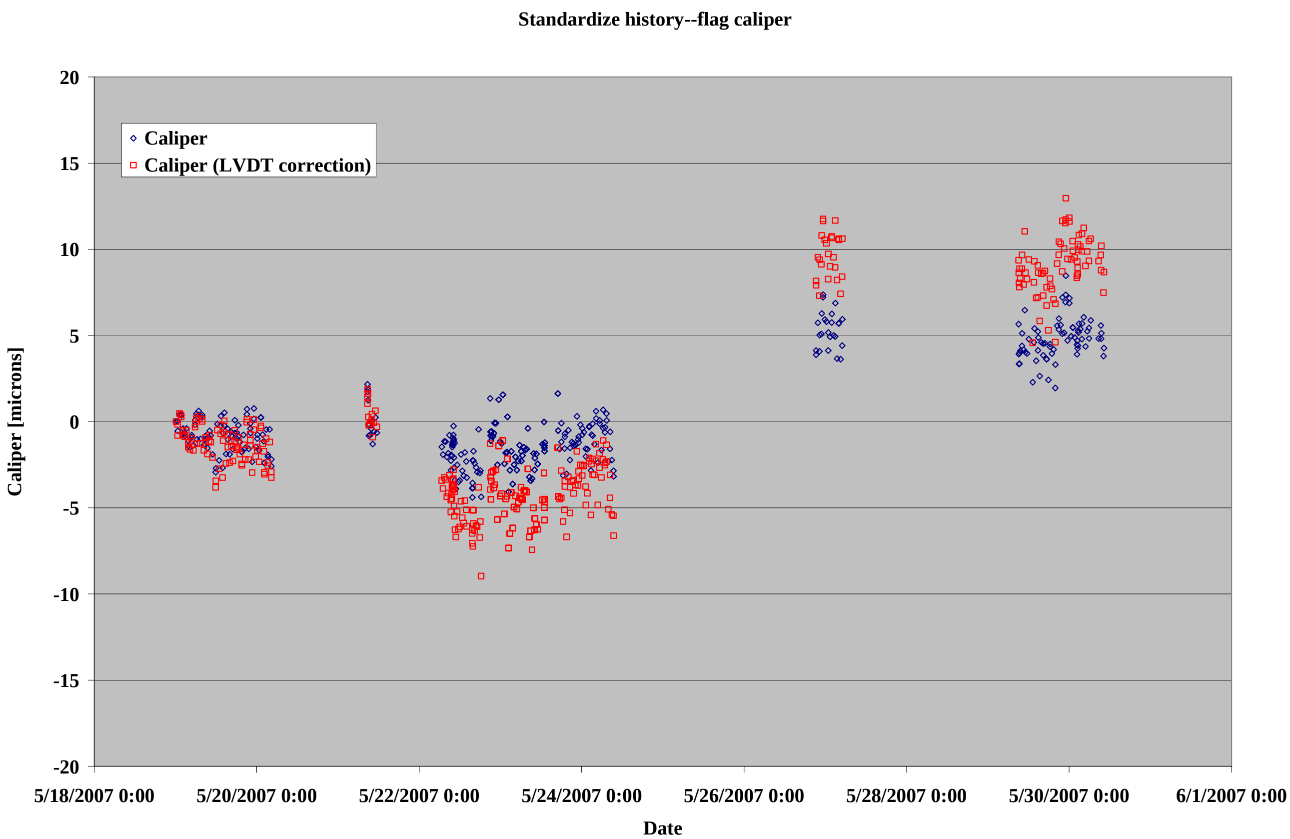

Figure 6-3 Example standardize flag values over time

6.4. Cleaning triangulation sensor windows

The windows should be cleaned every maintenance shutdown or if there is drift evident on the module displacements. First split the scanner heads while following the laser-safety precautions. To access the CML window:

1. Remove the three dome screws with a #2 Phillips screwdriver. One of these screws can be inserted into the threaded hole in the dome to be used as a handle.
2. Remove the four 2-56 screws which secure the keyhole plate with 5/64" Allen key, and
3. Carefully remove the keyhole plate.

To access the ZML window:

1. Remove the dust cover while noting the orientation,
2. Remove the three screws securing the centre keyhole insert (be careful not to drop the screws), and
3. Carefully remove the insert.

To clean the optics:

1. Blow dust off optics with clean compressed air (canned air is best),
2. Moisten a cotton-tipped swab with distilled water, shake off the excess and gently roll over the window. Try to roll in a smooth motion so only the clean part of the swab is in contact with the window. A back-and-forth motion may push dirt around the surface rather than cleaning it.
3. Repeat with isopropanol. Different solvents (water and alcohol) dissolve different contaminants. A combination is often better to use.
4. Inspect the surface to ensure there is no remaining dust.
5. Carefully replace the keyhole plate or keyhole insert.

When replacing the z-module dust cover, ensure that the embedded magnet lines up with the reed switch in the calibration module. Replace the cal-module dome ensuring that no hoses get pinched.

6.5. Checking calibration

The calibrations can be checked easily to see if there has been a change. A change might indicate a problem with one of the devices or dirt build up. To recalibrate, see Section 4.4. Save the calibration to disk, but it is not necessary to save the new calibrations to the recipe. The most important quantity for the calibration is the slope. A comparison can be easily made between the new and working calibrations. The slope should not change by more than 1 µm/mV. If there is a problem see Subsection 7.1.2.

6.6. Cleaning under CML dome and ZML dust cover

With time, dust can build up in the cavity between the keyhole plate and the underside of the cal-module dome. This can be easily removed with a damp cloth. Use the procedure in Section 6.4 to remove and replace the dome and dust cover. In most installations the vacuum dust removal fitting has not been attached due to a lack of need. If there is a rapid, problematic, dust accumulation, attach the vacuum.

6.7. Cleaning the air clamp slot

In some dirty mill environments the slot can become partially obstructed. Aside from a visual inspection, this may be evident from an upwards drift in the plenum pressure. The simplest way to clean the slot is to use a gap gauge, also known as a feeler gauge. A gauge in the range of 50 to 75 µm can be used. The gauge should be inserted into the slot (with the air off) and gently moved along the slot until it is clean.

6.8. Checking air tubes and air pressures

Check the air fittings, tubes, and pressures a few times a year.

- Visually inspect all the tubing to ensure there is no damage or evidence of pinching. Replace damaged tubing.
- Compare the purge pressures to the previously recorded values and adjust accordingly.
- Inspect fittings for evidence of air leakage.

6.9. Checking head-split interlock

Check the head split interlock periodically.

1. Put the scanner offsheet.

2. Split the scanner heads.
3. Use the laser viewing card to check for laser emission. At first the flag will be inserted, but after a few seconds it retracts.
4. If laser emission is seen, then the interlock has failed. Check that when the laser keyswitch is turned off the laser emission stops. If this is the case the head split switch should be removed from the system to prevent accidental exposure. Contact Technical assistance Center (TAC) for assistance in repairing the interlock.

7. Troubleshooting

Table 7-1 Functional failure troubleshooting

Symptom	Diagnosis	Section
Da Vinci laser power indicators off	Interlock circuit not closed	7.1.1
	SDAQ failure	7.1.7
Only 0 or ±10 V signals on laser devices	Laser device failure or obstruction or laser control PCBA failure	7.1.2
	Flag failure	7.1.9
Sudden change in laser calibration slope (magnitude of change > 2 μm/μV or unexpected jump to +10 V during calibration.	Dirt or obstruction in optical path or triangulation device failure (likely static or electrical short circuit)	7.1.2
Calibration slope not smooth or discontinuous within the measurement range.	Mechanical interference with dome perhaps caused by sheet guide or loose parts such as the cal-module laser bracket or the z-module translation frame.	7.1.6
Laser case temperature voltages outside of range (1.22 - 1.26 V)	Thermistor broken or circuit failure	7.1.3
Z-sensor readings not changing	Z-coil broken or electronics failure	7.1.4
Z-sensor temperature spread >0.2ºC	TEC cracked Thermal short circuit Electrical failure on PCBA	7.1.5
Dome does not move when commanded	Stepper motor failure Drive electronics failure (or disconnected)	7.1.6
Insert or retract lights never lit	Retract switch failure Start-up procedure not completed Mechanical interference	7.1.6
Pressure readings too low or do not change	Check tube and connections. If plenum pressure is actually low the sheet will not stay within the measurement range.	
Da Vinci voltages and measurements do not change.	Scanner down, SDAQ failure, or interface card failure	7.1.7
Staging error visible on laser caliper tab		7.1.8

Table 7-2 Performance failure troubleshooting.

Symptom	Diagnosis	Section
Drift in caliper readings	Dirt Natural variation	7.2.1
Profile error	Correlating with scanner x or y	7.2.2.1
	Correlating with Z or ZML	7.2.2.2, 7.2.2.5
	Correlating with CML	7.2.2.4, 7.2.2.5
	Errors correspond with maxima in head separation	7.2.2.3
Large difference between forward and reverse scans	Check scanner alignment and belt tension	

7.1. Functional failure troubleshooting

7.1.1. Suspected failure of interlock system

If it is not possible to achieve an ON state for the Upper Head Laser Power and Lower Head Laser Power indicators, it is likely that the interlock is not satisfied. Follow the following troubleshooting steps, while referring to the appropriate schematics (Figure 1-20, Figure 1-21, or Figure 1-22):

1. Check the signal levels on the **Upper Head Laser Displacement** and **Lower Head Laser Displacement** when a target is in place. Insert the sensor flag and position it with the stepper motor so it would be in measurement range of the laser devices. If signals other than ±10V are present on the displacement signals, it is likely that the lasers are in fact ON and the problem is the channel assignment for these contact inputs into the system.

2. Verify the keyswitch is on and properly connected.

3. Verify that the LSR indicator on sensor PCBs 6581500001 and 6581500002 are illuminated. If they are, current is flowing through the interlock to ground and the lasers are likely enabled and emitting.

4. Check for in-place switch failures. Physically examine the in place switches in both heads to make sure the button is depressed. Verify the continuity of the circuit with a DMM to ensure a closed circuit.

To do this, unplug the two-position plugs from position J3 of PCBs 6581500001, 6581500002 and measure across the contacts.

5. Verify the heads are both seated properly in their mounting holes. A reed switch in the calibration module senses the presence of a magnet mounted in the z-module and when sufficiently proximate, closes a switch, enabling current to flow through the interlock. If the modules appear to be well seated, temporarily insert a two position jumper into position J14 of the calibration head PCBA 6581500002. If this satisfies the interlock, it means that somehow the reed switch is not properly triggering. Ensure the magnet is oriented with the reed switch. Do this by rotating the PEEK dome of the z-module so the magnet is in the desired orientation. If this does not enable the interlock, contact TAC.

7.1.2. Suspected laser triangulation unit failure

A laser triangulation device failure is generally observed as an unchanging signal from the laser. A constant 0-V or ±10-V signal, with a target in measurement range usually indicates a problem. It is possible that there are more subtle symptoms which might indicate an impending failure. This might be indicated by a large calibration slope change or increasing nonlinearity in the calibration curve.

If the laser caliper sensor produces a constant reading, or if the reading is ±10 V:

1. Check that the laser power lights are lit on the interface PCBAs. If not, follow the interlock troubleshooting instructions (Subsection 7.1.1). It is unlikely that an interlock problem would cause only one laser to turn off.

2. Verify the Da Vinci measurement by measuring the appropriate test point on the interface board (Figure 1-10 or Figure 1-15). If the signals do not correspond, investigate the electrical connections and the SDAQ. One possibility is that the connector between the laser control board and the laser has been damaged. Carefully inspect the pins of the cable to ensure there is no damage.

3. Remove the keyhole plate, clean the optics, and inspect for dirt. If there is no obvious dirt check if there is a normal signal when the sensor is reassembled with the keyhole removed. If removing the

keyhole fixes the problem then this may be an indication that the laser power may be dropping and that a complete failure is imminent. Contact TAC for guidance. If this does not fix the problem,

4. Check that there is laser emission. Use the alignment tool (see Subsection 3.2.6.2). If the sensor has been previously aligned the alignment tool can be used to find the working laser position (it is unlikely that two would fail simultaneously). Centre the laser on the alignment tool using the translation stage. If there is no laser seen on the other side of the PSD PCBA, then there is a failed laser which requires replacement or factory repair.

5. When possible, turn off the scanner power and disconnect the laser caliper interface cable in order to remove power from the laser.

6. Set the laser caliper hardware removed flag if the scanner is required for other purposes. Keep the power off for at least an hour. If this fixes the problem, the most likely cause is that the laser overheated for some reason. If the scanner head temperatures have been normal, it is a sign that the laser might be about to fail outright. If this does not fix the problem:

7. exchange the two laser controller PCBAs. If the problem is transferred with the card replace the defective PCBA.

A sample calibration can be performed to examine laser displacement sensor performance. Execute a calibration and expect a nominal slope of approximately 150 µm/V for the laser displacement.

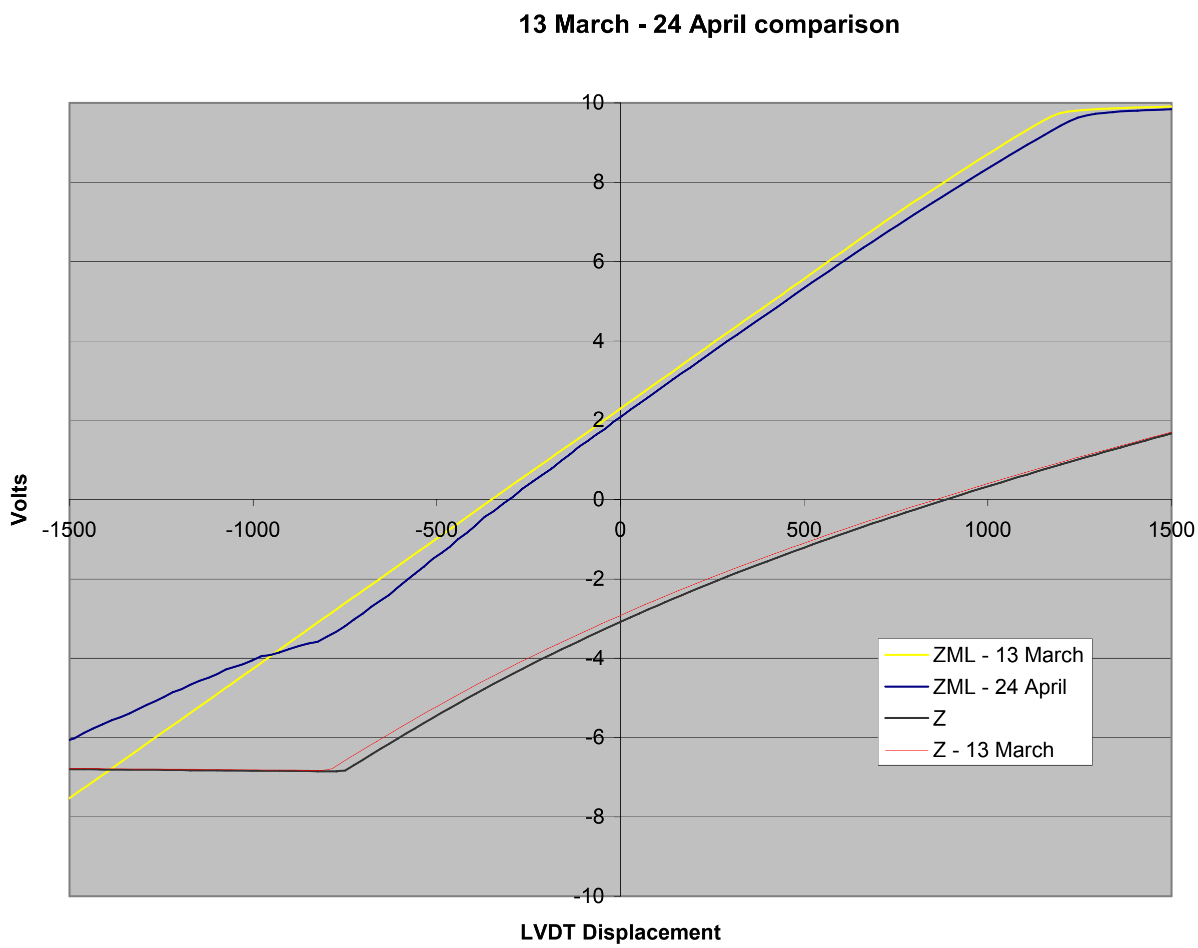

Figure 7-1Example of triangulation laser problem

In Figure 7-1, the Z sensor traces show that the dome is operating normally. The yellow trace acts as a baseline. The blue curve shows a change after five weeks. This problem is likely a laser which has reduced power.

7.1.3. Suspected failure of laser triangulation temperature control system

The laser case temperatures are held at approximately 41-44 °C by a resistive heater adhered to the side of the laser's aluminum housing. A signal level of 1.22 to 1.26 V is expected as a signal. The mathematical relationship is described in Section 1.4. Field site stabilities have been demonstrated to better than ±0.1ºC for this control system. Up to ±1ºC is acceptable.

Verify that the heater and thermistor are properly connected into the PCBA board. If a broken thermistor or heater is suspected, keep in mind that the thermistor resistance is 9.5 kΩ at 42ºC and 20 kΩ at 25 ºC and the heater resistance is 70 Ω.

7.1.4. Suspected z-sensor failure

A z-sensor failure would be evidenced by lack of sensible signal from the z sensor. Verify all connectors from the z coil to the electronics box to the z-module PCBA are properly connected.

Visually inspect the device, paying particular attention to where the electrical connections emerge from the z-coil. Ensure the cable is intact. Ensure that there are no cracks in the coil. The coil is brittle and could be broken by over-tightening the screws or by dropping.

A sample calibration can be performed to examine z-sensor performance. Execute a calibration and expect a nominal slope of approximately 330 µm/V for the z-sensor.

7.1.5. Suspected failure of z-sensor temperature control system

The z-coil temperatures are held at approximately 40ºC by a pair of thermo-electric coolers (TECs) connected electrically in series. The TECs are sandwiched between the z-coil and the aluminum dish (translating frame) of the z-module. A signal level of 1.76V is expected as a temperature signal which corresponds to 1.2 kΩ at the set point or 2.2 kΩ at room temperature. Field site stabilities have been demonstrated to better than ±0.1ºC for this control system. The mathematical relationship is described in Section 1.4. There is no trim pot. to manipulate this temperature set point. It is set in hardware on the interface PCBA.

1. Verify that the heater and thermistor are properly connected into the PCBA board.

2. Verify thermistor and TEC leads are in proper condition.

3. Try reducing or eliminating the z-module air purge flow temporarily. A case has been found of there being enough cold air flow such that the coilform could not reach its setpoint.

4. Measure the voltage applied to the TECs. This should be in the range 2 to 10 V. The maximum voltage is 11.5 V which would indicate maximum (and probably uncontrolled) heating or cooling.

7.1.6. Problems moving the calibration head dome, reaching the retract limit, or initialization error

The MSS initializes the laser caliper with the following procedure:

1. The MSS verifies that both laser power indications are ON. These indications are required if the MSS is to continue the script.

2. MSS sets the motor direction to DOWN.

3. MSS then sends a large number of steps to the motor—the number is settable in the RTDR (**/Scanner x/Mss/Ssx nc caliper/Setup/Steps full retract**). The number of steps must be sufficiently large so that the dome will retract and trigger the electro-mechanical home (retract) switch on the base of the stepper motor.

4. When the retract switch indicates HOME, the calibration module interface card resets its internal step count to 0. From there, the internal count monitors the state of the insert limit state. There is no hardware physical insert limit switch; the insert switch is simply indicated after the interface card measures a specific number of up-going counts.

5. Finally, Da Vinci sends another series of steps based on another RTDR value (**./Scanner x/Mss/Ssx nc caliper/Setup/Steps away from retract**) to move the dome up into the LVDT measurement range and it iterates the dome position until the dome is at the so-called onsheet voltage of the master signal.

There are a few problems that can be encountered in this procedure: the lasers may not be on, the stepper motor may not be operational, the home switch may not be reached or may be faulty, or the insert switch may be set to an unreachable position.

7.1.6.1. Stepper motor failure

If the stepper motor does not run, the dome cannot move. This will cause start up errors on Da Vinci because the software will not be able to retract the dome to satisfy the home switch at startup. To test the stepper motor's ability to move, control the motor through the **MSS Setup Diagnostics** display.

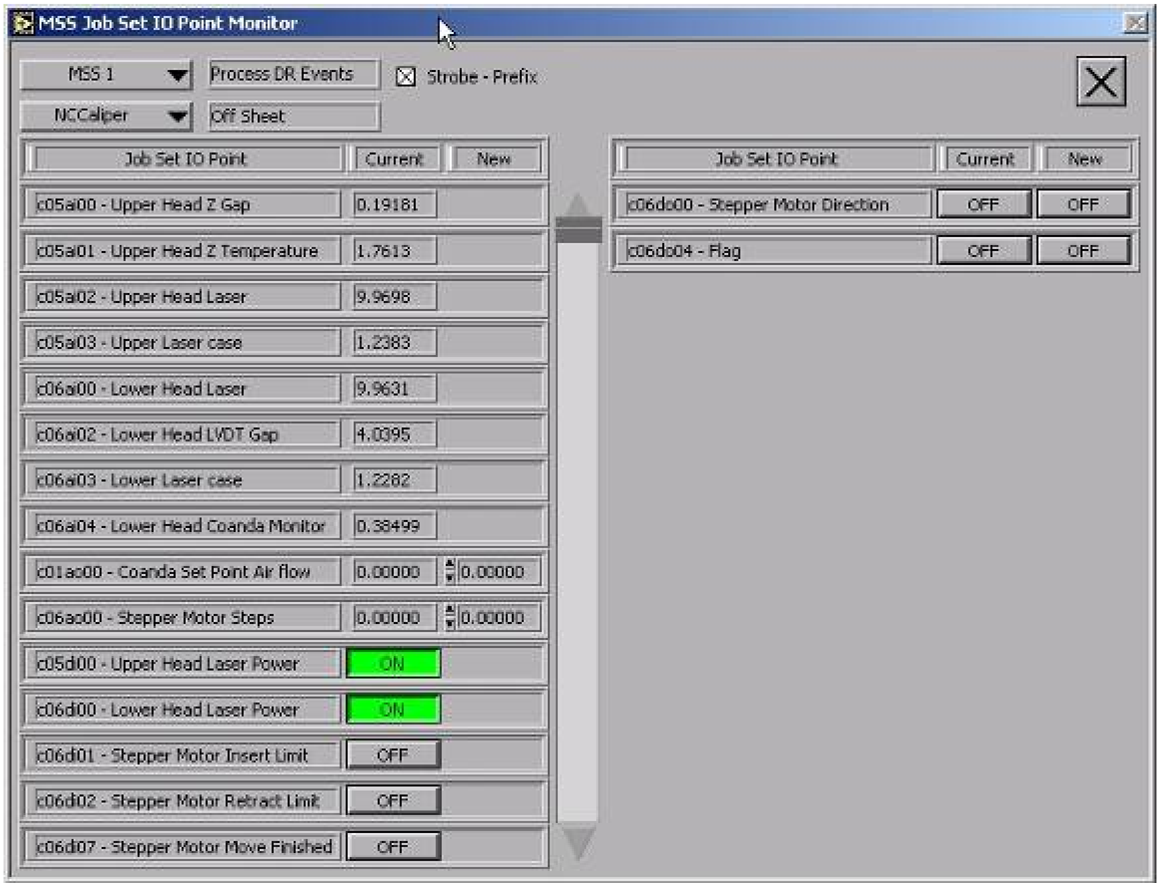

Figure 7-2 MSS Setup Diagnostics Display

One way to confirm the dome is actually moving is to verify that simultaneously the signals of the z-module laser, the calibration module laser, the z-sensor, and the LVDT all react in a sensible fashion. See Figure 2-1 to recall expected signal levels as a function of dome position. Be sure to be outside the device deadbands to properly interpret signal levels.

Another way to determine if the dome can move is to physically examine it at the scanner. For example,

1. Request ten thousand steps towards retract (stepper motor direction set to **OFF**) and the dome retracts into the scanner head. The **Stepper Motor Retract Limit** indicates **ON**.

2. Verify as well that the dome can travel out of this position by selecting ten thousand upward steps. The **Insert Limit** eventually shows ON and on physical inspection the dome appears to be extended into the gap.

3. If dome motion was not observed during these attempts, verify the stepper motor connector is solidly connected into position J7 of the interface board.

4. Next, verify that the internal harness linking the interface card to the SDAQ card (6581800048) is properly installed. Dome motion requires a combination of functions from both the SDAQ card and the interface card. Also verify that the communication indicator is lit (**A OK**). If a new SDAQ has just been installed it must have part number 6581800013 and must have the correct jumper settings (see Subsection 7.1.7).

5. If the sensor passes all these tests it is likely that the stepper motor or the interface card has failed.

7.1.6.2. Retract limit not reached

1. If the dome appears to move, but the retract limit is never satisfied, first ensure that the dome motion is not physically impeded.

2. Ensure the home switch harness is solidly connected into position J13 of the calibration module interface card. Otherwise, there is a possibility that the home switch itself has failed. If one attempts to move the home position incorrectly the leads may be damaged. The most reliable fix is to replace the stepper motor assembly.

7.1.6.3. Insert limit not reached

The insert switch is not a physical switch. However, a certain number of steps must be successfully completed from the home position. If there is a physical interference this condition will not be satisfied. This physical interference may be caused by a physical stop on the system. If the sensor stops at the physical stop before the desired number of steps then the number of steps requested is too high. The database entry at must be reduced ((**./Scanner x/Mss/Ssx nc caliper/Setup/Steps away from retract)**.

7.1.7. Suspected PCBA, connector, or power track failure

Often it is necessary to electrically troubleshoot the system. For this reason electrical test points are provided on the interface PCBAs (6581500001 and 6581500002). The test points and LEDs can be located with Figure 1-10 and Figure 1-11. The signal identifications can be made with Table 1-1 and Table 1-2. Furthermore the laser driver card and SDAQs have LEDs which can be examined for basic functionality. The laser driver card has three green LEDs which indicate the state of the power to the board +5 V, -15 V, and +15 V. If one of these is not lit then it is likely that there is a power supply problem. The SDAQs have three LEDs. One indicates board power and the other two indicate the communication status. Only the one that is labeled **A OK** should be lit. If this is not lit,

1. Check the cables between the SDAQ and the laser interface board,
2. Check the scanner PCDAQ card (either 05436600 or 055382). There are numerous LED indicators on this card. The numbers correspond to the DAQ channels. The channels are determined by the config board set used and controlled by Da Vinci and the MSS. A transmission light, labeled TD or TX, ON indicates that the PCDAQ is trying to communicate with the SDAQ. The receive light, marked RD or RX, indicates a completed circuit.
3. If a defective SDAQ is suspected, try swapping the upper and lower SDAQs. It is unlikely that two SDAQs would fail at once.
4. If an SDAQ is to be installed on the cal-module, ensure that it is has part number 6581500013. This SDAQ has different firmware (installed on U16) from the SDAQ used on other sensors.
5. Also check that the jumper for W1, W2, and W3 are as follows: removed, installed, installed.

CAUTION

There are static-sensitive components on the PCBAs. Adequate anti-static precautions must be taken before touching these boards. A properly grounded conductive wrist strap must be worn and the PCBAs must be in static bags when being inserted or removed from the scanner heads.

7.1.8. Staging error

Table 7-3 Staging error codes and interpretation

Error code	Interpretation
1	Dome retract, limit switch not found
2	Dome move away still in retract limit switch
3	Dome move away still in insert limit switch
4	Staging voltage, not found
5	Staging voltage, dome in retract limit switch
6	Staging voltage, dome in insert limit switch
7	Calibration Step, dome in insert limit switch
8	Simple Move, dome in retract limit switch
9	Simple Move, dome in insert limit switch

If a **staging error** is seen on the **Laser Caliper** display, narrow down the cause through the alarm log and with Table 7-3. The error code also appears at **./Scanner x/Mss/Ssx nc caliper/Setup/Staging error code**. It is not considered a large problem if the staging error is seen only occasionally, especially during calibration. If it occurs too frequently first ensure that the dome can move freely in the sheet guide (see Subsection 3.2.1), attempt to change the settings for **Max iterations to find position** and **Position tolerance (volts)** in the **Dome Movement Setup** section of the **NCC Setup** display. If this does not work and the error seems to occur when the dome is retracting, ensure that there are no mechanical interferences under the dome.

7.1.9. Flag failure

The flag piston is such that if there is no air pressure the flag will remain closed. The most likely cause of a flag failing closed is a loss of air pressure. Check all the fittings air tubes for pinches. A second common cause for flag failure is a mechanical obstruction sometimes caused by part wear. To test for this, dismount the dome from the translation bracket and disconnect the air pressure. Move the flag in and out by pushing on the slider attached to the piston. It is usually possible to determine the cause of the failure. If it is a failed part, it is possible to obtain a new dome assembly as a spare part (6581800062) or a new flag assembly (6581800138).

7.2. Performance failure troubleshooting (measurement present but of poor quality)

7.2.1. Absolute value drift

Absolute value drift can be an early indication that a measurement device is losing its accuracy. In particular, if the device is drifting continuously in a monotonic way, it is likely that one or both modules are suffering from accumulated dust build up. Debug this effect systematically.

1. Ensure both z-module and calibration module purges are properly plumbed with a clean and dry air supply and are expelling air.

2. Perform the next step to determine if a specific module is preferentially contributing to the drift.

NOTE:	**Clean one module at a time, let the system run, record and observe the results before cleaning the other module!**

3. Move the scanner head offsheet.

4. Clean the z-module head with a swab. Return to scanning. Allow approximately twenty minutes of scan time for stabilization. Observe any changes in absolute value of the measurement. Go offsheet again.

5. Clean the calibration head. After stabilization, observe the change in reported measurement. This exercise should identify if one of the

modules is preferentially accumulating dust. If so, iterate on the purge level of the module that appears to be contributing the most error.

6. Repeat this procedure over many days to understand the dynamics of your particular system. Determine the rate of soiling and adopt an appropriate cleaning schedule to maintain proper measurement.

If the variation in absolute value is bounded and cyclical with periods of approximately ten minutes. The error is usually due to the cooling water cycling on and off and a consequent thermal expansion and contraction of the gauge itself. This error can be minimized by employing the LVDT correction in the Da Vinci software.

If the variation appears to be correlated roll changes it is likely that the paper machine has a tension profile that repeatedly changes through the roll. This must be addressed though air pressure and measurement position optimization.

7.2.2. Profile error

The NCC is a geometric sensor that makes optical triangulation measurements in an industrial environment; so it follows that the dominant mechanisms that generate measurement error are gauge misalignment and cleanliness. Dirt can influence profile as well. The following sections review the most common profile errors experienced in the field.

Note how the gauge tends to behave. Recall the simple geometric picture of the gauge displacement measurements. It has been observed that the air clamp is sufficiently strong so that the sheet tends to remain at a fixed distance from the dome as the heads travel across the sheet to within ±50 µm. (Some systems will deviate from this behavior, some times in specific locations across the CD. For example, a region with higher or lower tension than the rest of the sheet will sag towards the clamp or resist being drawn to it. Stabilizer bars near sheet edges also add significant local variation to the sheet nominal position and tension.)

More specifically, if there is variation in the head gap, it tends to be seen in both the z-sensor, and the z-module laser. The profile of the z-sensor directly records the sheet guide gap - which is typically the order of several hundred microns - and the z-module laser's displacement will be reported to be a very similar profile.

If the gauge profile is reporting in error, it is recommended to attempt to determine with which of the following functions the error best correlates: scanner head CD wander, X(x); scanner head MD wander, Y(x); the displacement of the sheet relative to the calibration-module, $Z_{CHL}(x)$; and the head separation function, $Z_Z(x)$. Once a dominant correlation has been identified, review the next sections discuss for what can be done to intervene in the system.

It is common, especially during commissioning, that several error mechanisms participate simultaneously. If this is the case, address the dominant error mechanisms first, then reanalyze the system and reprioritize the issues.

Collect and analyze the data offline, where explicit relationships can be better seen—profiles can be difficult to correlate visually on the Da Vinci display. It is preferable to collect the data with the datalogger and export it in a Matlab format. Contact Vancouver Engineering for assistance.

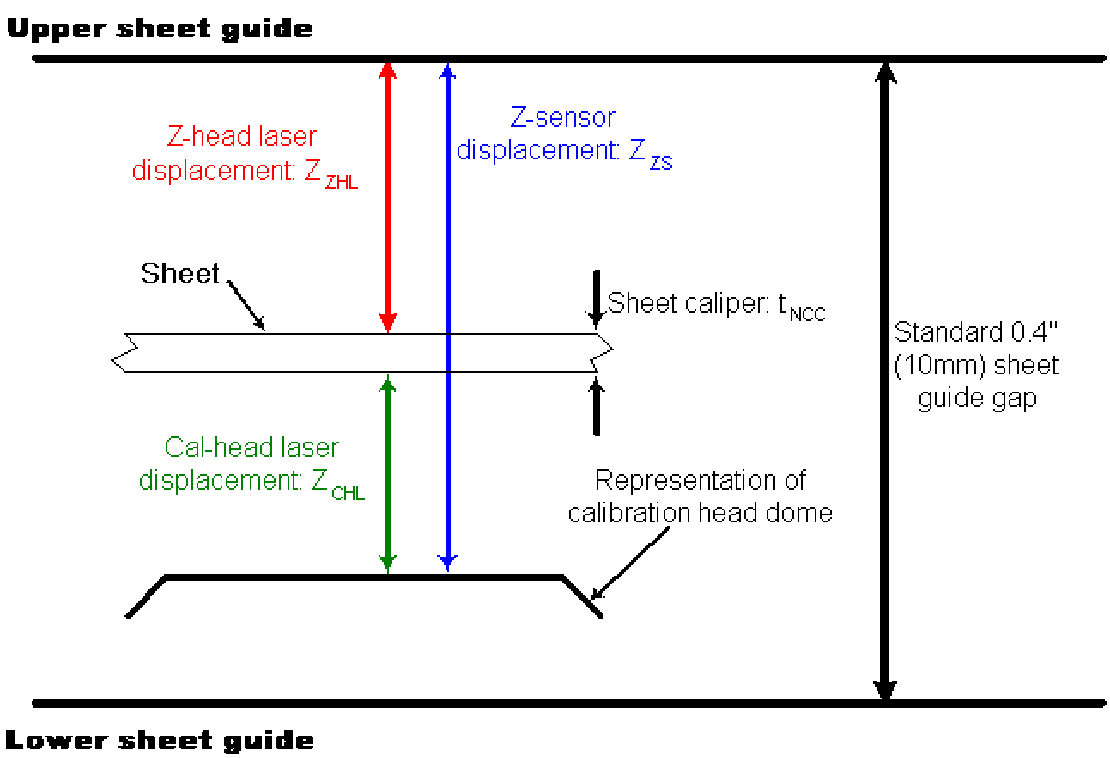

Figure 7-3 Basic uncorrected NCC measurement

7.2.2.1. Profile correlates with x or y profile

Head wander, in either the X (CD) and Y (MD), has been observed to correlate with caliper error in the past. Examples presented in this section are extracted from field trials and are considered representative. See Figure 7-4. In this example, if may appear that caliper error and the X(x) profiles are related. Directly attempting to correlate them suggests the speculation is true, but you can also extract a correlation coefficient from the exercise. Figure 7-5 includes the note that the caliper error and the X(x) profile are correlated by the scale factor dt_{Ncc}/dX=-0.011 µm/µm. This scale factor can interpreted to mean that for every millimeter of scanner head excursion in the CD direction, the caliper suffers an error of 11 µm.

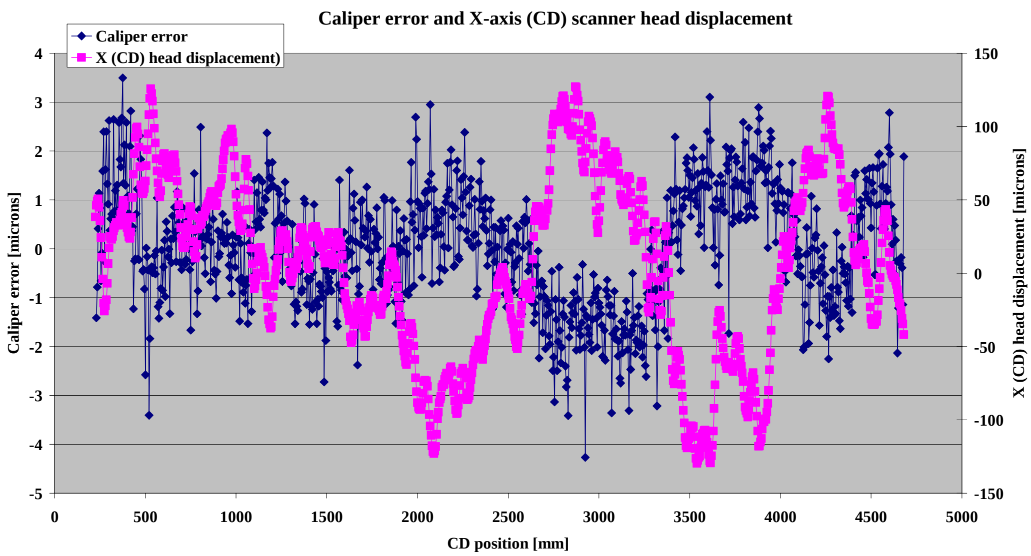

Figure 7-4 Caliper error looks like X (CD) profile of scanner head wander

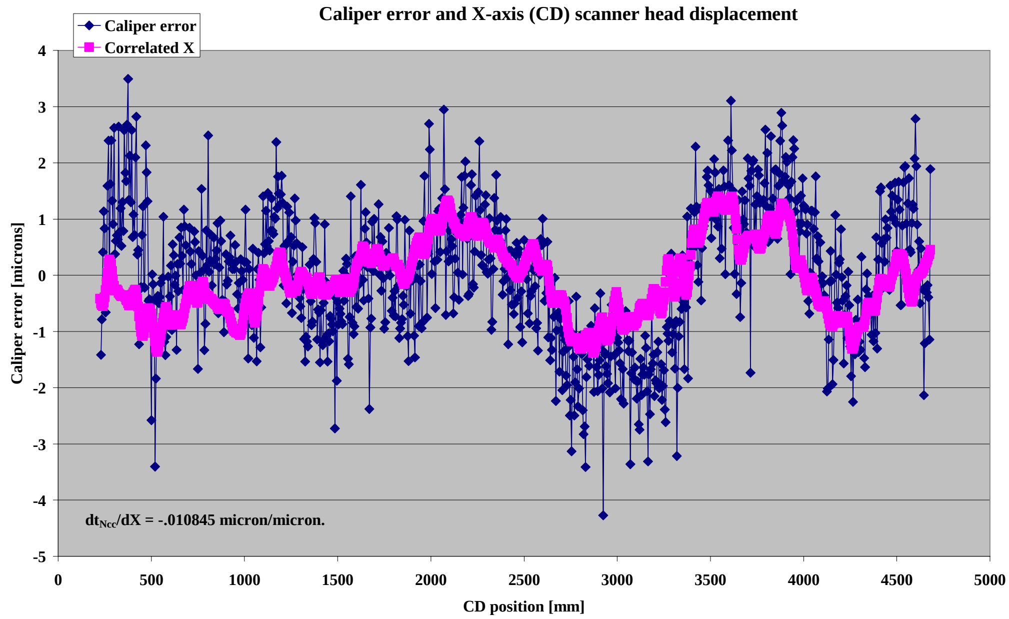

Figure 7-5 Correlation demonstrates that error is very likely a relationship with CD scanner geometry

Geometrically, an explicit CD sheet angle can be extracted from this correlation $\theta_x \approx 11/1000$ radians. First, make a judgment on the whether the absolute wander of the heads is excessive or if the sensitivity (angle) is too high. The performance specification for the Da Vinci scanner ±650 µm in the CD. However, tuning can generally improve this performance.

If the outright wander of the scanner is too large, perform conventional scanner alignment techniques to bring the CD performance of the scanner back into specification.

If the angle is too high, reduce this error by one of these means:

- Verifying that the air clamp slot is not preferentially obstructed on one side. This might cause asymmetric sheet positioning above the clamp.
- Sampling the performance at different airclamp airflows, attempt to determine if the error can be reduced by iterating on flow rate through the air clamp.
- Adjusting the gauge alignment slightly in the CD and determine if this tweak influenced the measurement performance. If the gauge alignment is badly off in the CD, this correlation can be induced.

- If rollers are present, ensuring the rollers are parallel to the sheet surface.

If these hardware interventions are not productive yet the error appears to be stable in time, a profile correction can be used to remove the remaining error. It is somewhat risky to implement a profile correction more than ±1 μm in magnitude.

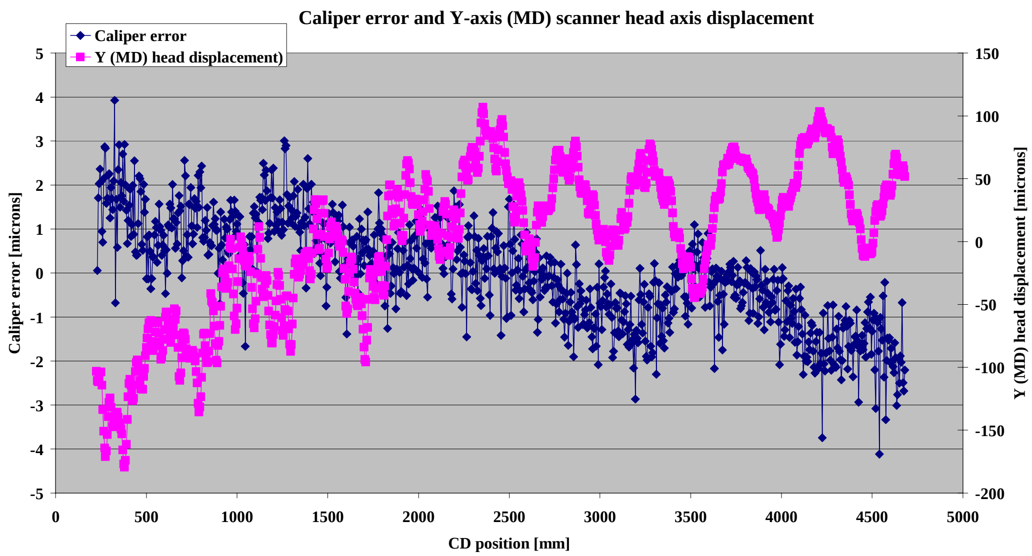

Figure 7-6 Caliper error looks like Y (MD) profile of scanner head wander

Similar comments can be made regarding the correlation of caliper error with the MD motion of the scanner heads, Y(x). Again, it is recommended to explicitly examine a suspected relationship offline and attempt to determine the scale factor by which the MD-profile and the caliper error correlate.

In the example of Figure 7-6and Figure 7-7 a scale factor (implied MD sheet angle) of 0.013 μm/μm is obtained. Again, first seek to determine whether the movement of the scanner itself or the gauge's sensitivity to scanner movement is the excessive factor. Da Vinci scanner specifications state a maximum MD wander of ±250 μm, but targeted scanner tuning can provide better performance than this.

It could be a misalignment/sheet position influence. The MD direction is the direction in which the variation of the sheet shape over the air clamp is expected and thus prone to error. Conversely, by virtue of symmetry little variation is expected in the CD direction. See Figure 3-13 for a 3-D representation of the sheet as held over the air clamp. If the scanner appears well behaved, but the sensitivity is viewed as excessive, try one of these means:

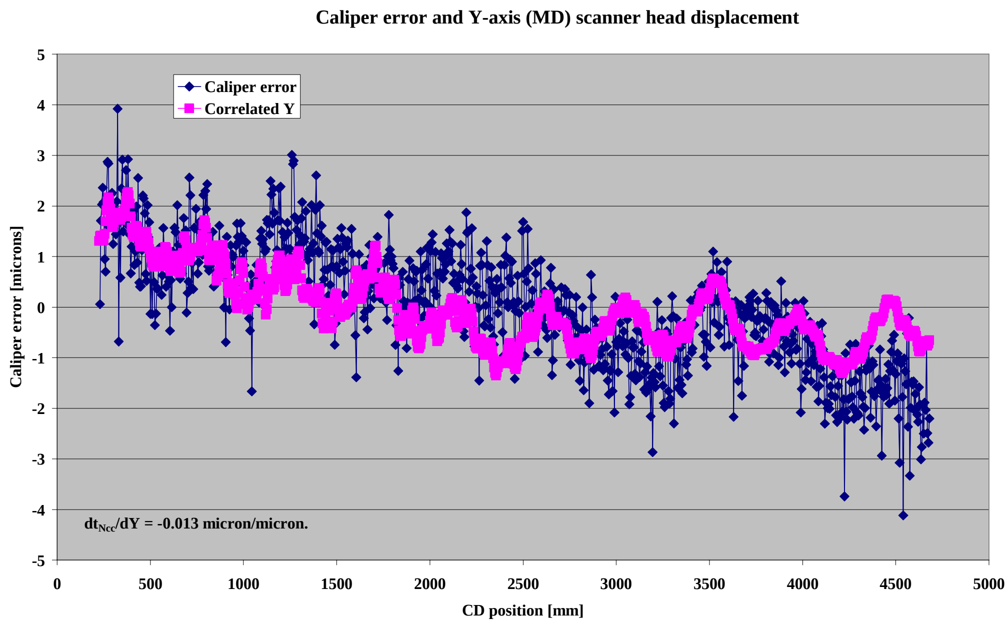

Figure 7-7 Correlation - error is very likely related to MD scanner geometry

- Confirm that the sheet is in a desirable position for measurement and the calibration–head laser is properly aligned with this position. If this error is large—that is, greater than ±2 µm—redo the procedure in Subsection 3.2.6.
- If a resetting of the calibration-module laser is performed, the re-alignment of the z-module laser is also necessary.
- Air clamp flow rate may have an influence on the sheet position. Iterate on this parameter to determine optimum tuning.
- If it is determined that the sheet shape varies significantly in time, likely due to weight and tension variation in the process, add sheet-stabilizing rollers to the scanner to mitigate this influence.

7.2.2.2. Profile correlates with head separation profile

Unlike X and Y wander, the non-contacting gauge is expected to be robust to variations of the head separation across the CD. Specifically, this is why the z-sensor is included in the gauge design. If the reported NCC profile appears to correlate with the scanner's z-profile, it can be said that there is a lack of cancellation between the z-sensor displacement and the z-module laser's reported displacement. Consider the basic relationship for caliper again:

$$t_{NCC}(x) = Z_Z(x) - Z_{ZHL}(x) - Z_{CHL}(x) + \Delta t_o .$$

Equation 7-1 Repeated basic caliper relationship

To illustrate the effect consider the extreme case of dirt build-up: the z-module's optical triangulation laser is completely blinded by dirt and it provides a profile that is completely flat—as if it sees none of the sheet variation at all. In this case, the caliper error could be written as the difference between the reported caliper and the correct caliper. In detail it can be seen that the error would resemble the negative of the z-module laser profile,

$$\Delta t_{NCC}(x) = t_{NCC}^{reported}(x) - t_{NCC}^{true}(x) = [Z_Z(x) - Z_{CHL}(x) + \Delta t_o] - [Z_Z(x) - Z_{ZHL}(x) - Z_{CHL}(x) + \Delta t_o]$$
$$\Delta t_{NCC}(x) = Z_{ZHL}(x).$$

Equation 7-2 Caliper error equivalent to z-module laser profile if the laser is completely obscured

The displacement of the head gap should be similar in shape and in magnitude to the displacement seen by the z-module laser. This is because of the ability of the air clamp to be able to hold the sheet to a displacement with low variation relative to the surface of the air clamp. There is a positive correlation between caliper error and the head separation. More typically, there is only a fraction of the correct z-module laser displacement reported. Only a fraction, α, of the correct z-module displacement is under-reported:

$$\begin{aligned}\Delta t_{NCC}(x) = t_{NCC}^{reported}(x) - t_{NCC}^{true}(x) = \quad & [Z_Z(x) - (1-\alpha)Z_{ZHL}(x) - Z_{CHL}(x) + \Delta t_o] \\ & - [Z_Z(x) - Z_{ZHL}(x) - Z_{CHL}(x) + \Delta t_o]\end{aligned}$$
$$\Delta t_{NCC}(x) = \alpha Z_{ZHL}(x).$$

Equation 7-3 Caliper error profile correlates positively with z-module laser displacement if laser under-reports variation

See examples in Figure 7-8 and Figure 7-9.

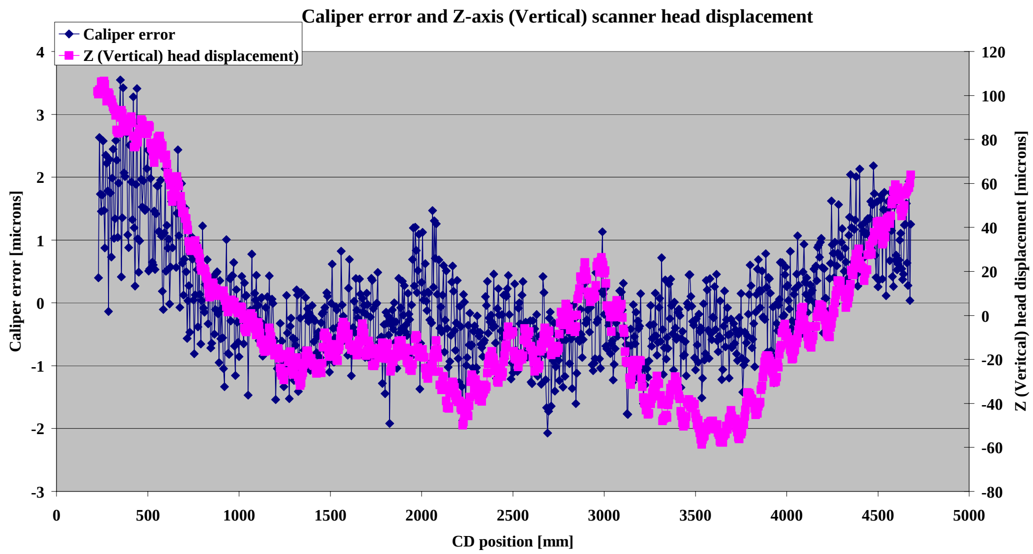

Figure 7-8 Caliper error "looks like" vertical head separation

The example of Figure 7-8 shows that the absolute variation of the head separation is perhaps 130 µm peak-to-peak. This is a well-behaved scanner and the gap should be tolerated by the gauge (the specification is ±125 µm.)

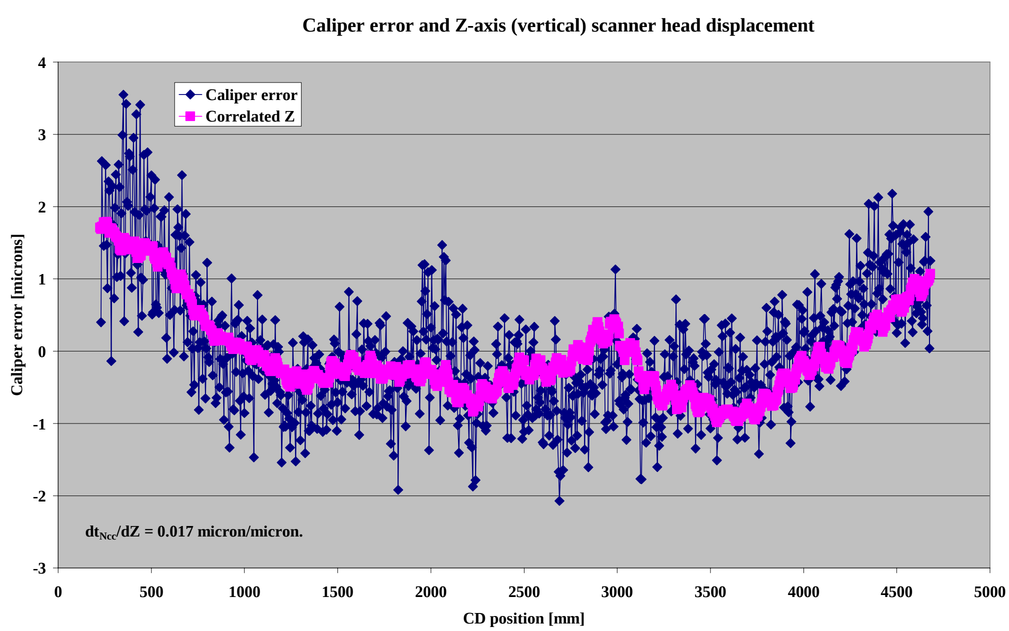

Figure 7-9 Correlation - caliper error due to lack of z-sensor/z-module laser cancellation

Performing an explicit correlation, there is a scale factor of 0.017 µm/µm. Physically, this scale factor indicates that for every 1000 µm of head separation, the caliper profile in error by approximately 17 µm. This result indicates that the cancellation between the functions $Z_Z(x)$ and $Z_{ZHL}(x)$ is poor. In particular, it indicates that the z-sensor is reporting more displacement than the z-module laser.

In this example, the z-module is reporting a function with a peak-to-peak magnitude of approximately 130 µm, while the z-module laser is reporting a similar shaped function, but with a magnitude of approximately 127 µm—the difference appears as profile error. This can be interpreted as either increased sensitivity of the inductive proximity sensor, or reduced sensitivity of the z-module triangulation sensor. It is less likely that the calibration of the z-sensor spontaneously changes than the optical device. If this error is what is found, note the calibration slope for all three devices as they are currently being used to compute caliper.

To read this information, see Section 4.3. Then, perform a renewed calibration following the instructions of the Section 4.4. It would be expected that some clue as to the misreporting device can be found by examining the newest calibration constants. Imagine if the z-module laser were totally blinded by a surface encrusted with dust. As the calibration proceeds, the signal level from the device will not change, but the displacement of the dome will still be correctly reported from the LVDT. The calibration slope will include the correct assessment of the displacement excursion, ΔZ, but an attenuated reporting of the voltage change, ΔV, so that the calibration slope $\Delta Z/\Delta V$ will be higher than the nominal setting of 150µm/V.

For example, if it is found that the newer z-module laser slope is somewhat higher, it is very likely the z-module laser optical path is dirty. Entering the renewed calibration values should improve the profile. The degree to which the calibration slope may be in error can be approximately estimated by examining the error relative to the absolute value of the head separation profile. For the example of this section, the absolute excursion can be imagined to be in error by three microns in a total 130 µm. This is a proportional error of 2.3%, in Equation 7-3, this would correspond to α. It is likely that the calibration slope is out of date by the same proportion—that is, a calibration nominally entered as 150 µm /V now requires 153.4 µm /V.

Be aware as well if the device has been calibrated in a dirty environment, then cleaned without renewed calibration, the opposite effect can be seen.

Over time, note the z-module purge flow settings. Iterate this value if necessary. Ensure air to the sensor is as oil-free and humidity-free as possible.

It is unlikely, but possible, that it is the z-sensor that is in error. The z-sensor has not been seen to demonstrate failure modes in which it degrades. It provides either the correct signal or no signal. However should the z-sensor be suspected, verify the coil temperature. Specifically, compare the coil temperature at calibration with the onsheet temperature. It is theoretically possible that the offsheet temperature is sufficiently different than the onsheet temperature to induce a different effective onsheet calibration relationship. As previously stated, this is a low probability event. Temperature variations in general are rarely the source of profile errors because it is unlikely they are repeatable from scan to scan.

7.2.2.3. Errors correspond with maxima in head separation

One particular type of head-gap related error appears as spikes or dips in the caliper profiles which correspond to the maxima in the head separation. This problem is almost certainly due to one of the sensors going out of its range during the scan. The solution is to adjust the dome position or if the problem is related to excessive scanner vibration to reduce the vibration.

7.2.2.4. Profile correlates with calibration module laser profile

In most applications, the air clamp is sufficiently strong so the sheet can be imagined to travel with the air clamp. The aerodynamic forces exerted on the sheet by the air clamp are uniform in the CD and the position of the sheet above the air clamp is a function of the ratio of aerodynamic forces to sheet tension. Systems with sheet tension variations are expected to show displacement variations in their calibration-module displacement profiles.

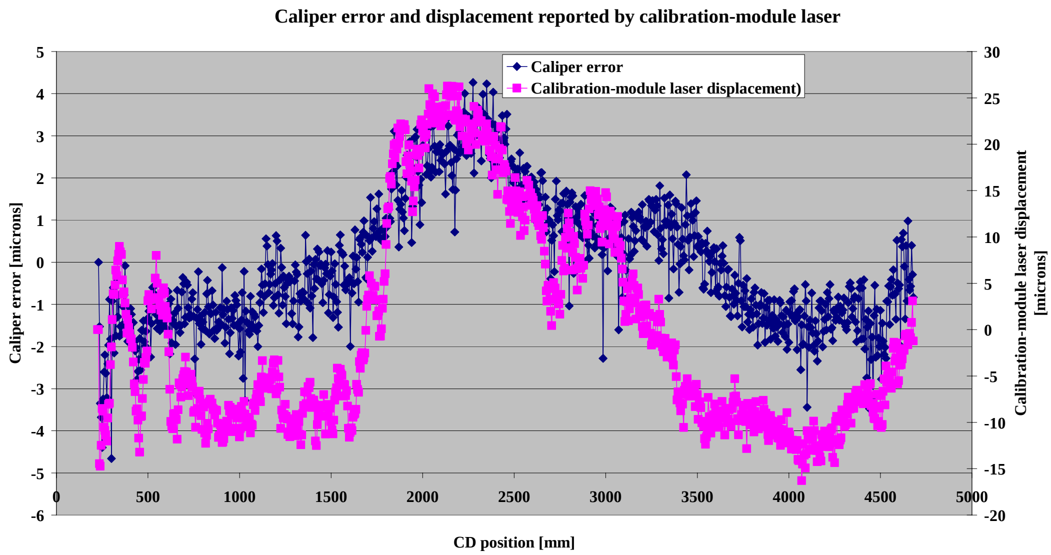

Figure 7-10 Caliper error correlated with calibration head laser displacement

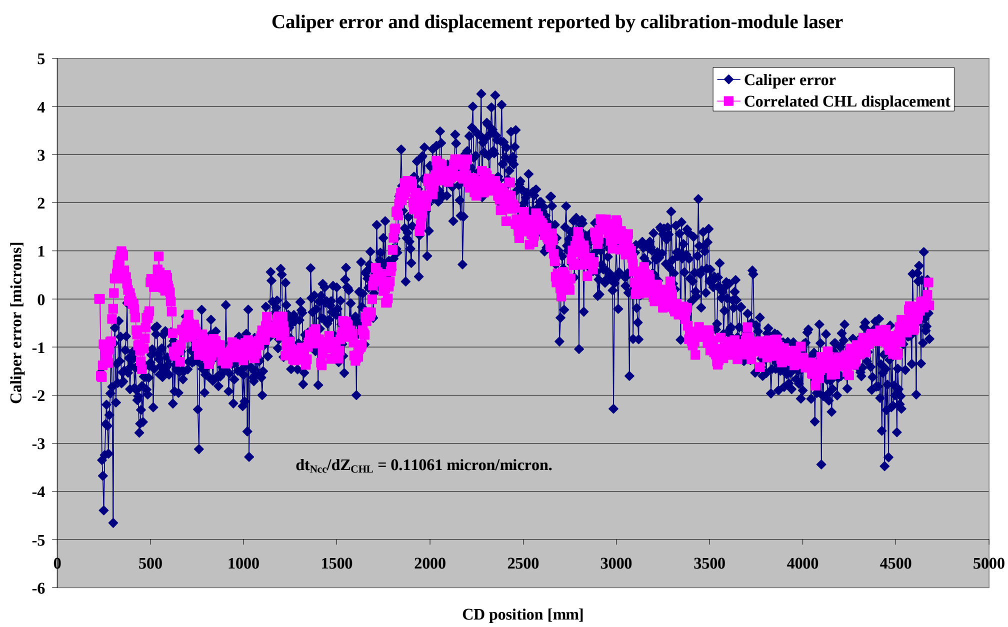

Figure 7-11 Caliper error correlates with calibration head laser displacement function

An example is presented in Figure 7-10 and Figure 7-11. The appearance of the calibration-head laser profile in the caliper profile suggests that calibration slope of the laser is incorrect. The most likely reason for this is dirt in the optical path. The caliper error could be written to show that an under-reporting calibration head laser that just slightly less than unity

$$\Delta t_{NCC}(x) = t_{NCC}^{reported}(x) - t_{NCC}^{true}(x) = \left[Z_Z(x) - Z_{ZHL}(x) - (1-\beta)Z_{CHL}(x) + \Delta t_o\right] - \left[Z_Z(x) - Z_{ZHL}(x) - Z_{CHL}(x) + \Delta t_o\right]$$
$$\Delta t_{NCC}(x) = \beta Z_{ZHL}(x).$$

Equation 7-4 Caliper error will be positively proportional to the calibration head laser displacement function if the calibration head laser is under-reporting displacements

This β is the expected required adjustment to the calibration slope. In the example above, it is approximately 11%. This is a significant amount that suggests a calibration slope of 165 µm/V (150µm/V × (1+β)). This is a value that is clearly in error and is observable on a calibration. Some relief on recalibration and on re-entry of the calibration results is expected, but if soiled optics are a persistent problem, note the calibration-module purge flow settings. Iterate this value if necessary. Ensure air to the sensor is as oil-free and humidity-free as possible.

7.2.2.5. Calibration error resulting in profile errors

Another type of calibration error can occur. If the dome is obstructed in its movement during calibration, the force can result in a distortion in the dome such that the LVDT does not provide an accurate reference. During calibration this may seem fine but when measuring the z-sensor and LVDT measure the dome position while the lasers measure the sheet position. If there is a slope error in the calibration this will be manifest in a profile error that appears as one of the profiles. If the interference appears during only part of the dome travel the error may be different for different on sheet positions.

8. Storage, Transportation, and Disposal

8.1. Storage and transportation environment

In order to maintain integrity of components, storage and transportation of all equipment must be within these parameters:

Duration of Storage	Acceptable Temperature Range	Acceptable Humidity Range
Short Term (less than one week)	-20°C to 45°C	20-90% non-condensing
Long Term	-10°C to 40°C	20-90% non-condensing

8.2. Disposal

Honeywell supports the environmentally conscious disposal of its products when they reach end of life or when components are replaced.

All equipment should be re-used, recycled or disposed of in accordance with local environmental requirements or guidelines.

This product may be returned to the Honeywell manufacturing location, and it will be disposed using environmental friendly methods. Contact the factory for further details and instructions.

Guidelines for disposal of equipment by Honeywell or the customer for scanner-specific materials are:

- Remove all belts, wheels, and non-metallic parts (except plastic) from the scanner and dispose through the local refuse system. Recycle plastic parts.
- Wire and cabling should be removed and recycled; the copper may have value as scrap.
- Electrical and electronic components (for example, solder, circuit boards, batteries, and oil-filled capacitors) should be recycled or handled as special waste to prevent them from being put in a landfill, as there is potential for lead and other metals leaching into the ground and water.
- Metals should be recycled, and in many cases have value as scrap (for example, beams, enclosures, mounting and retraction components, fasteners and hardware).
- Except where identified in this chapter, the sensor does not contain hazardous or restricted materials.

9. Documentation

This Chapter provides sample installation drawings for

- Laser caliper (top level assembly)
- Cal-module assembly
- z-module assembly
- Spares List (current as of 2007)

NOTE:	Figures depicting product diagrams or schematics are included in this manual for illustration and explanation purposes only, and may not match the drawing that is currently available/shipped with your product.

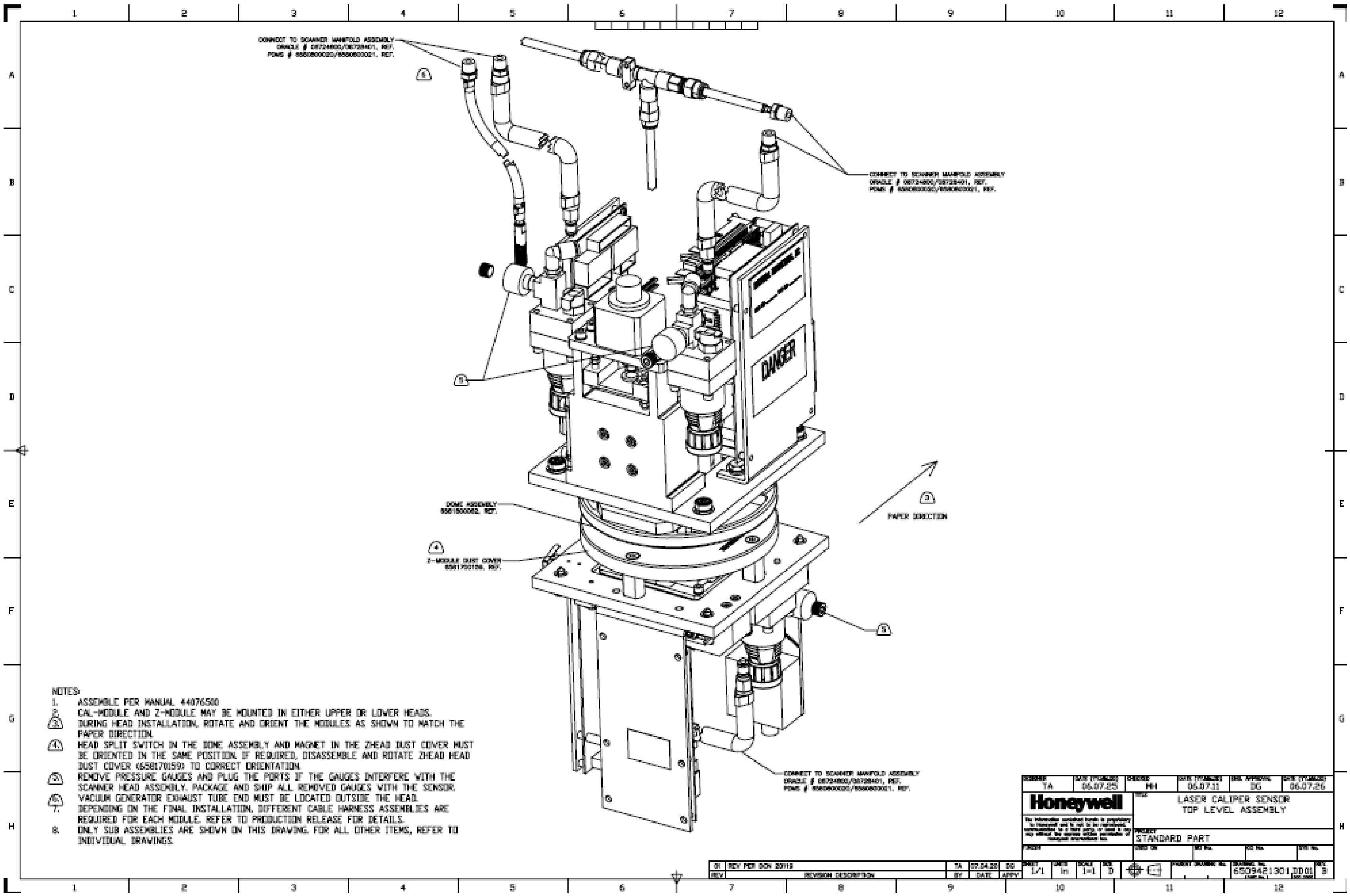

Figure 9-1 6509421301: laser caliper sensor top-level assembly

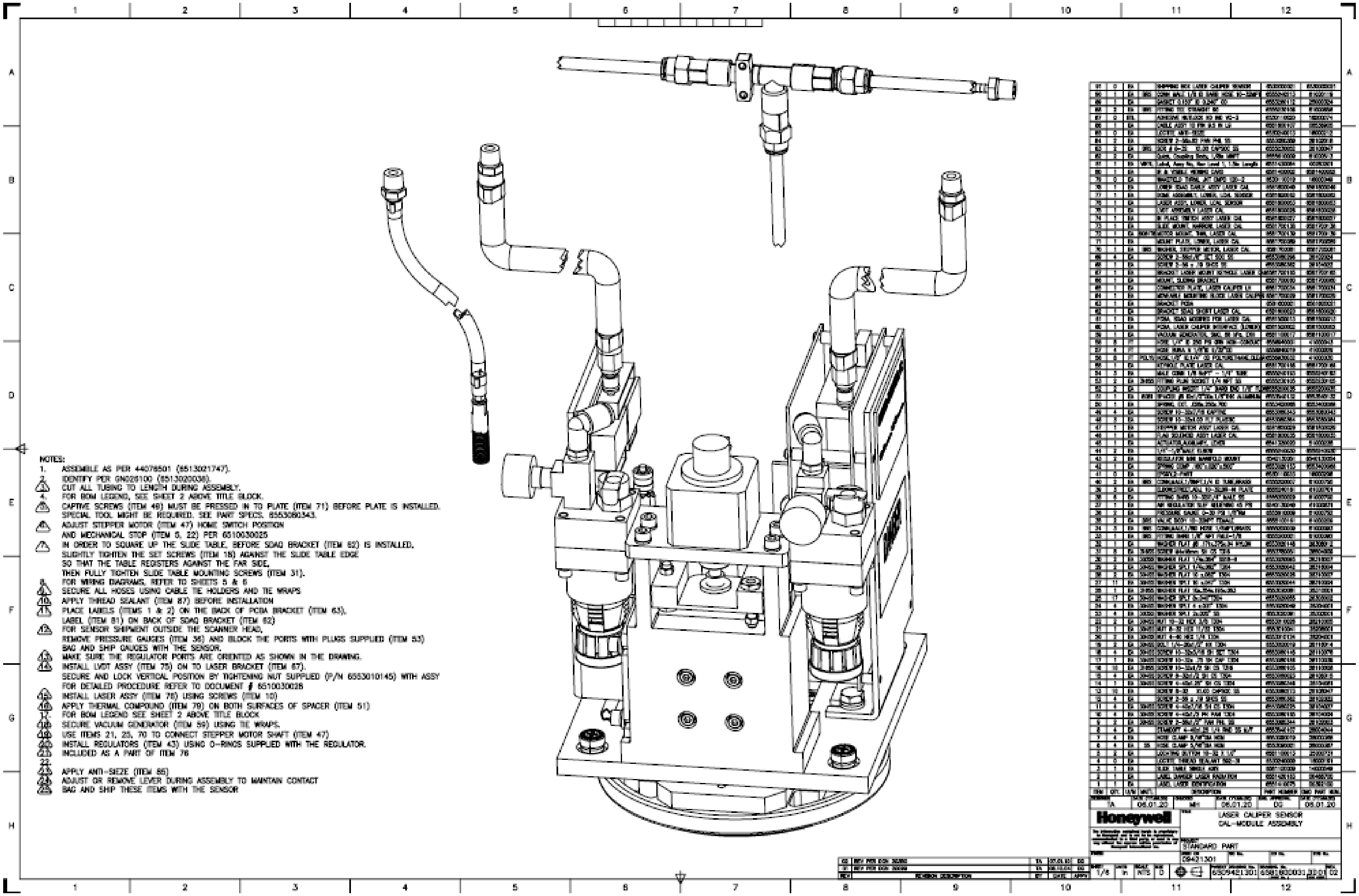

Figure 9-2 6581800031: laser caliper sensor cal-module assembly (1/ 6)

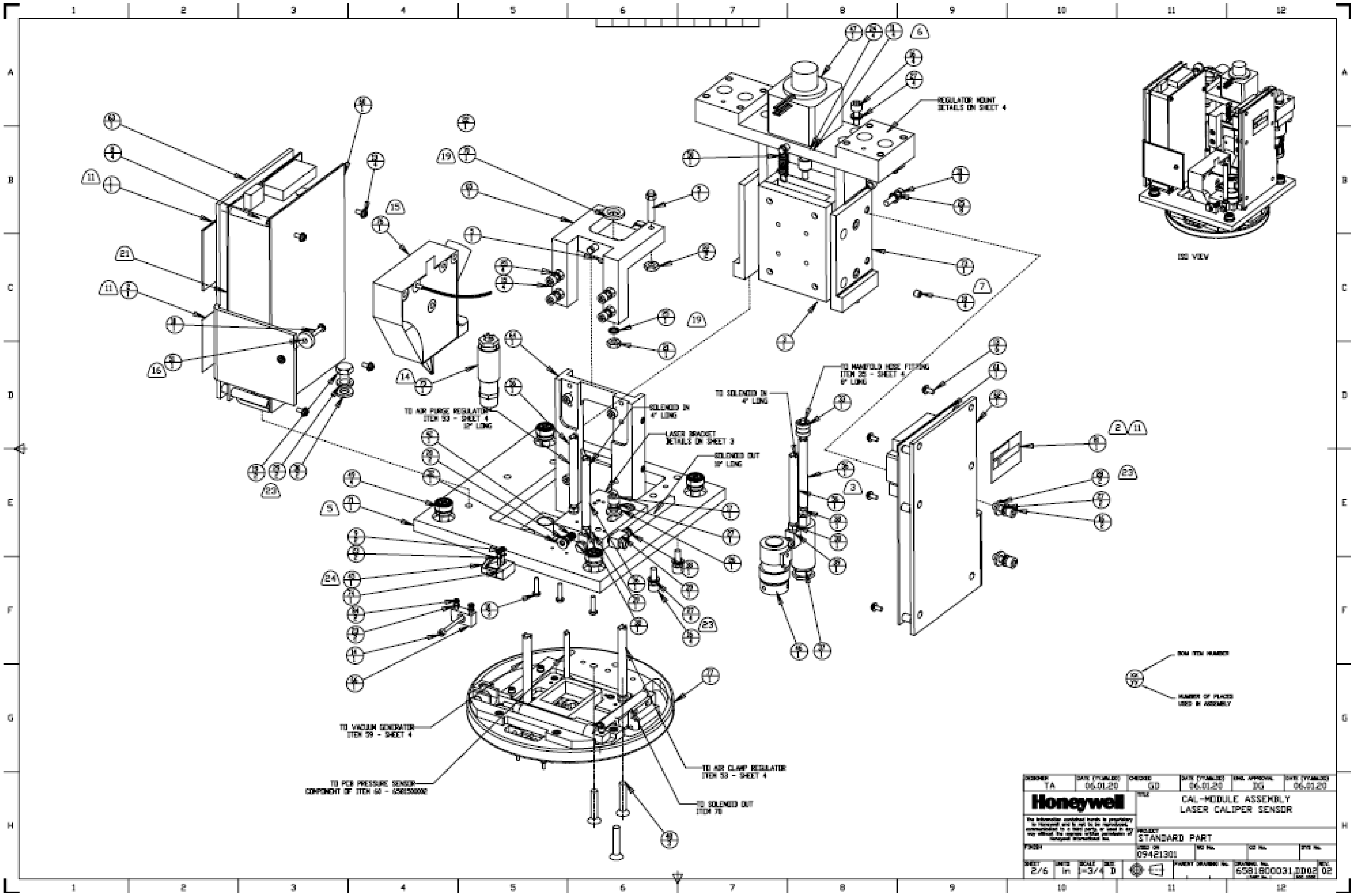

Figure 9-3 6581800031: laser caliper sensor cal-module assembly (2/6)

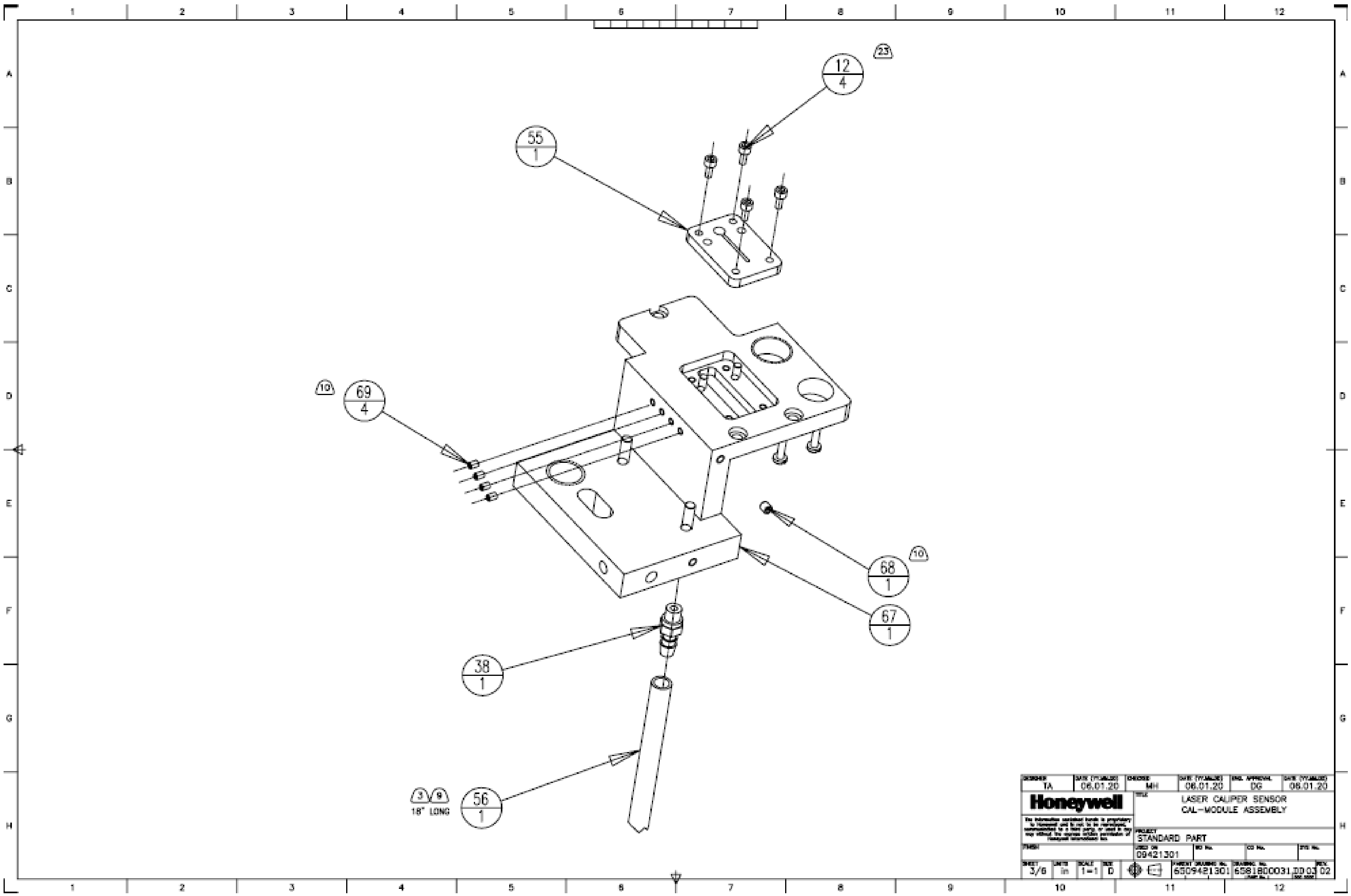

Figure 9-4 6581800031: laser caliper sensor cal-module assembly (3/6)

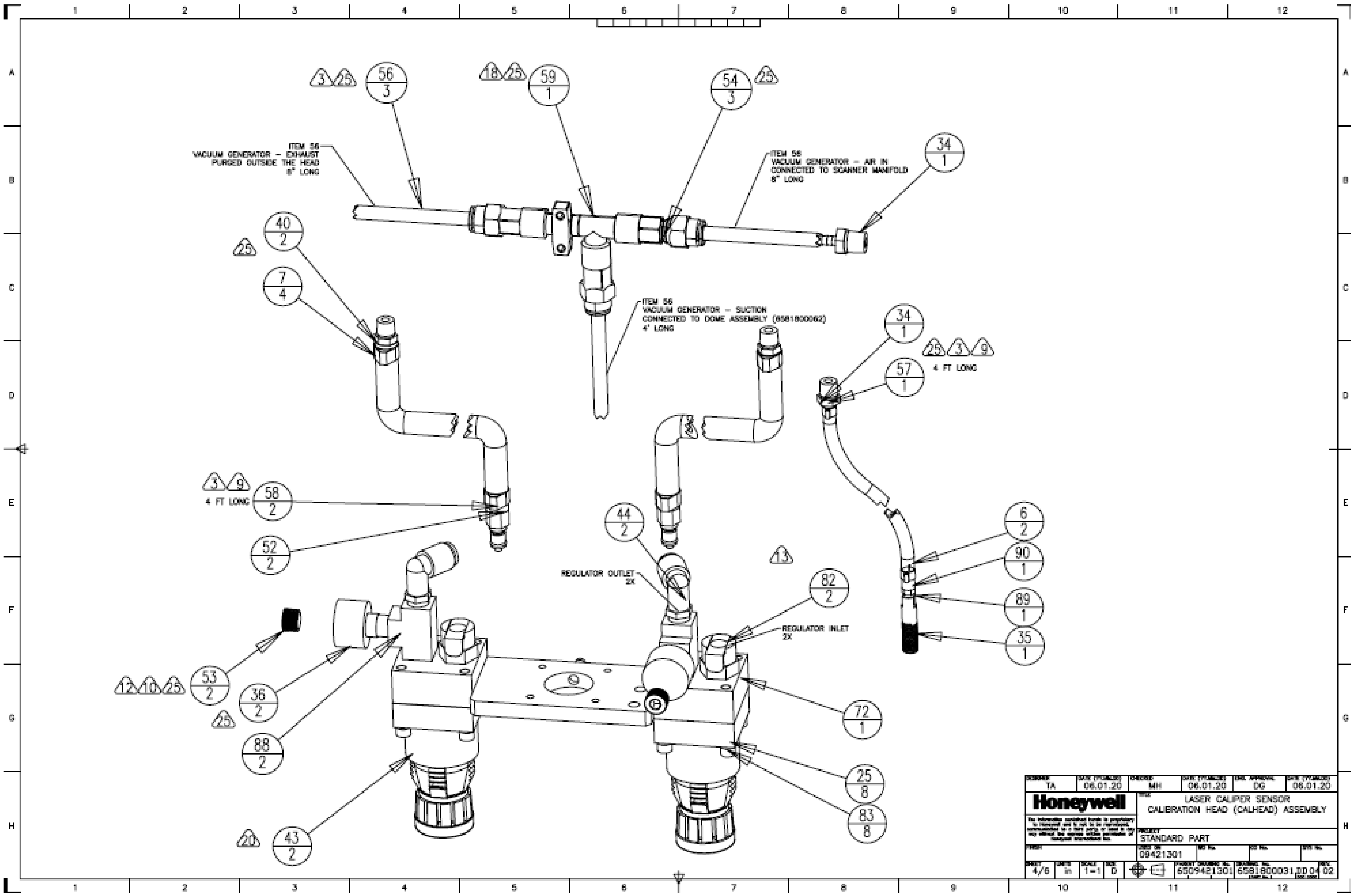

Figure 9-5 6581800031: laser caliper sensor cal-module assembly (4/6)

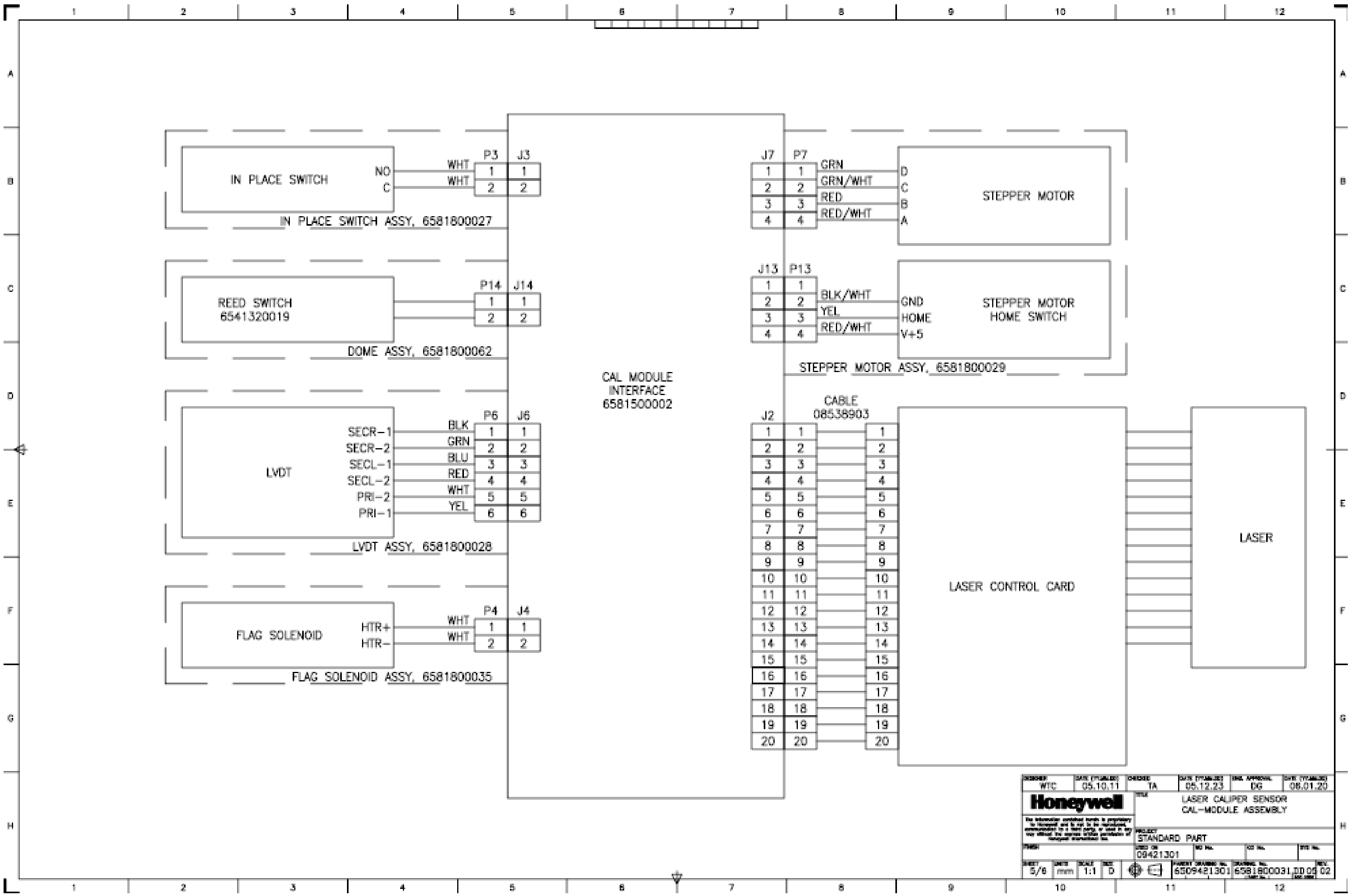

Figure 9-6 6581800031: laser caliper sensor cal-module assembly (5/ 6)

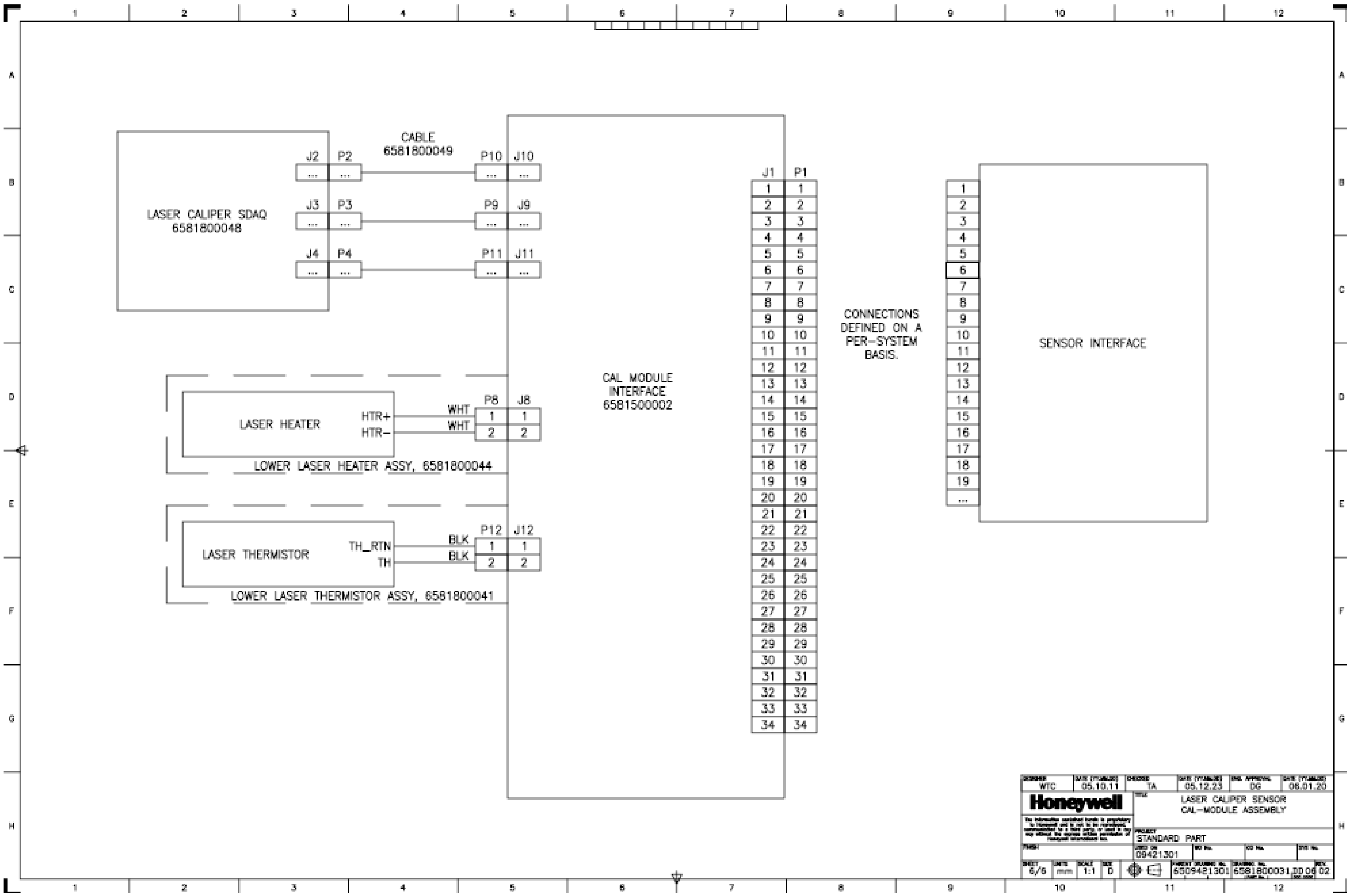

Figure 9-7 6581800031: laser caliper sensor cal-module assembly (6/ 6)

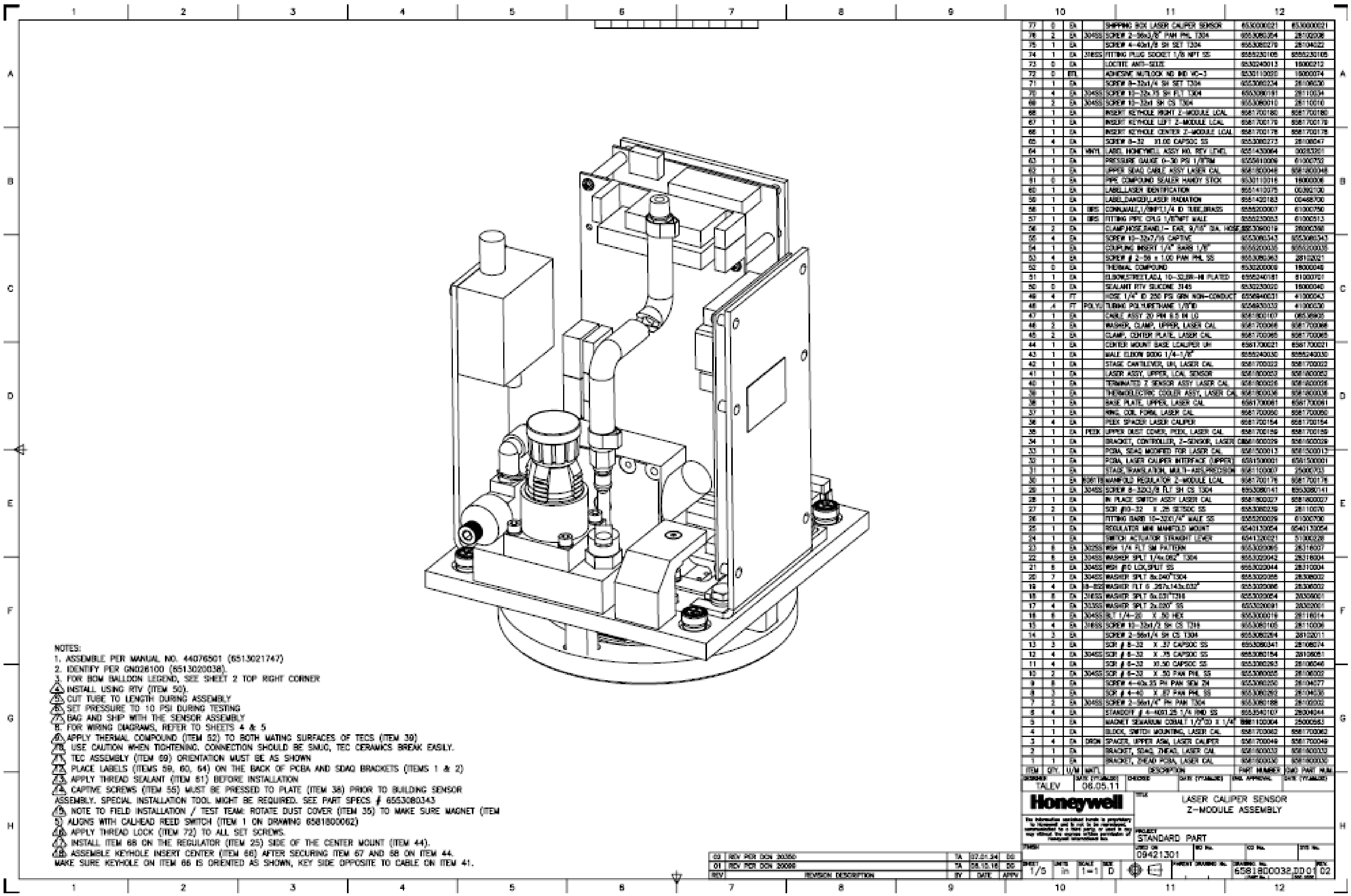

Figure 9-8 6581800032: laser caliper sensor z-module assembly (1/5)

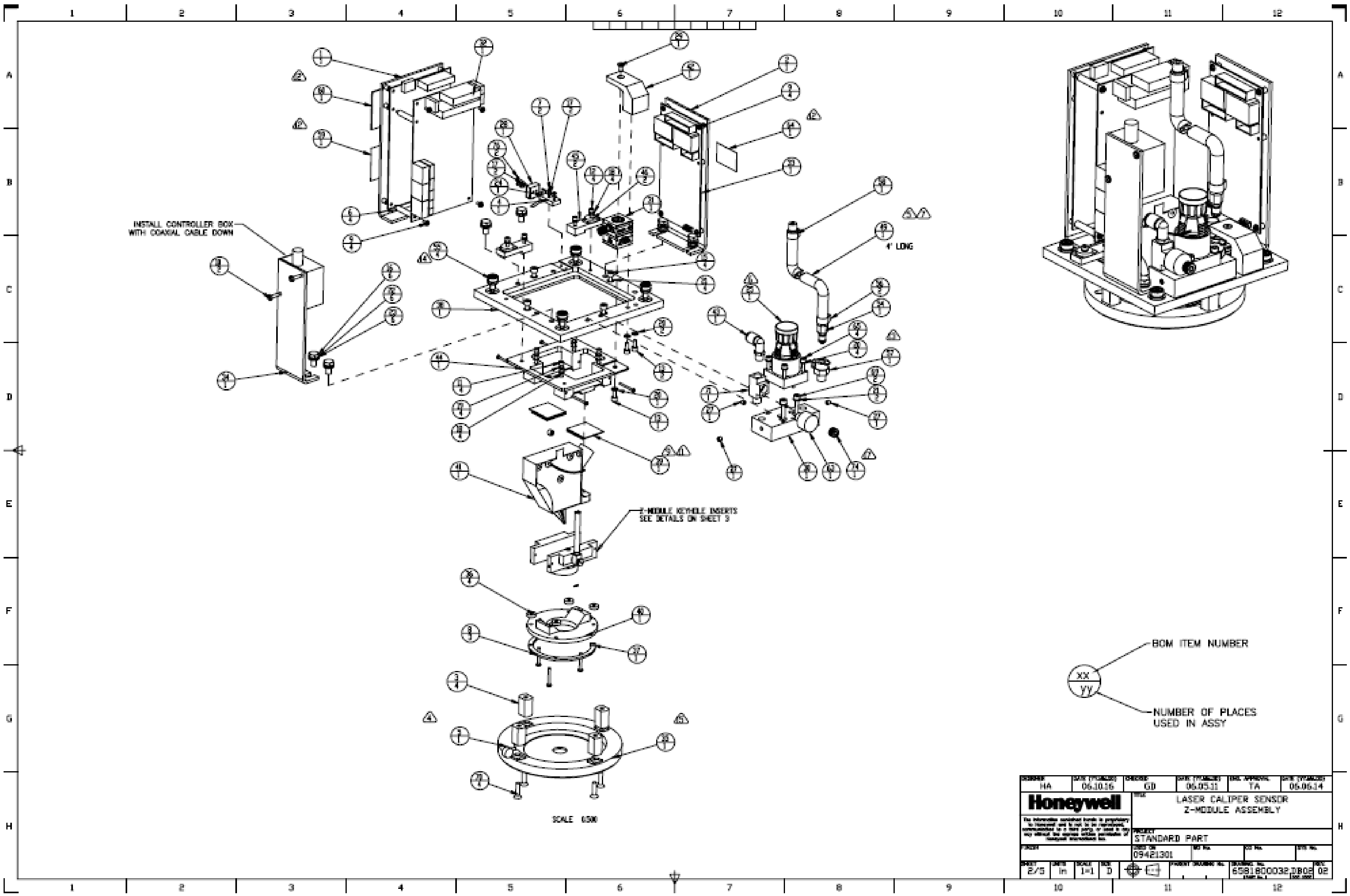

Figure 9-9 6581800032: laser caliper sensor z-module assembly (2/5)

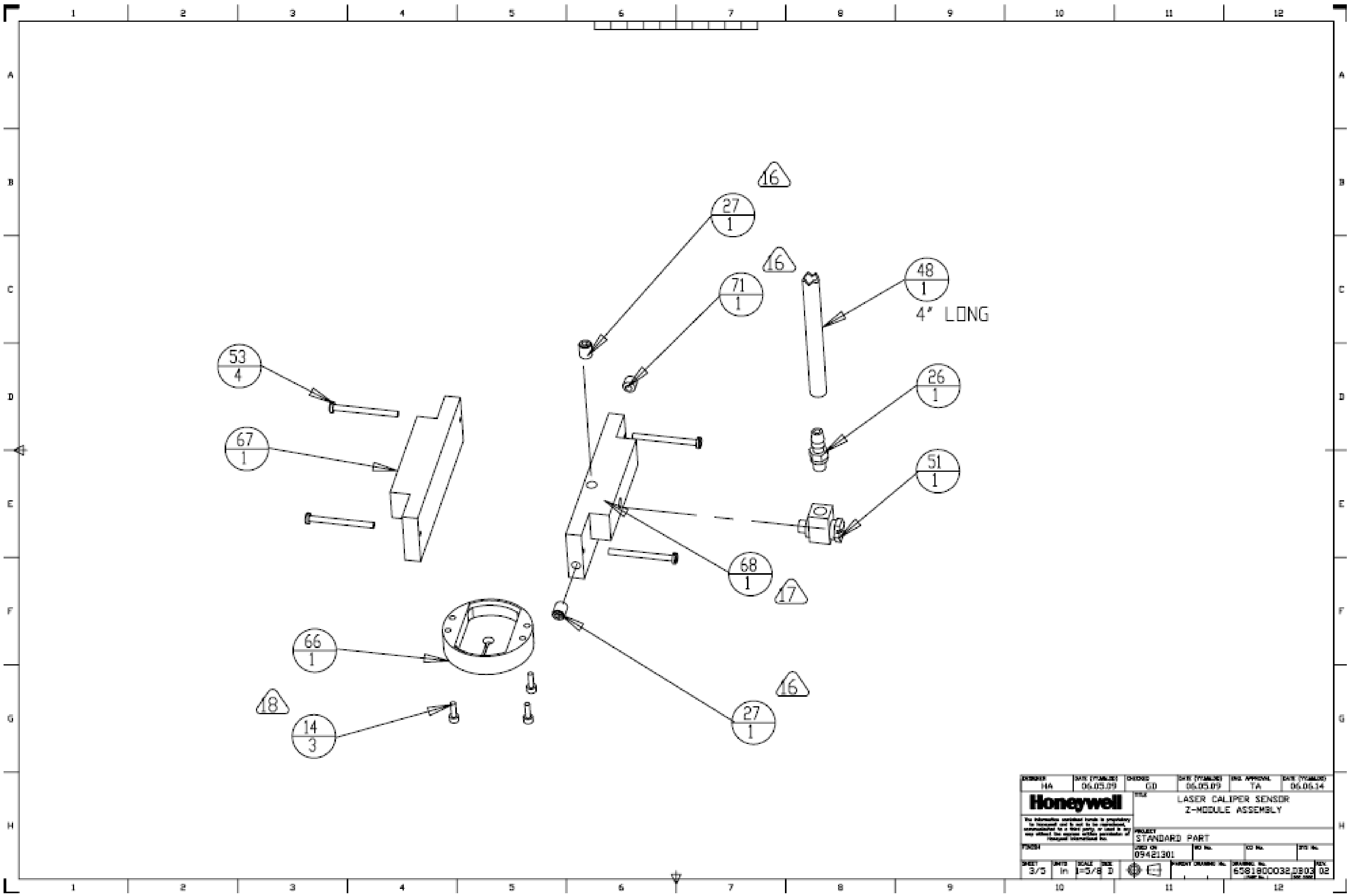

Figure 9-10 6581800032: laser caliper sensor z-module assembly (3/5)

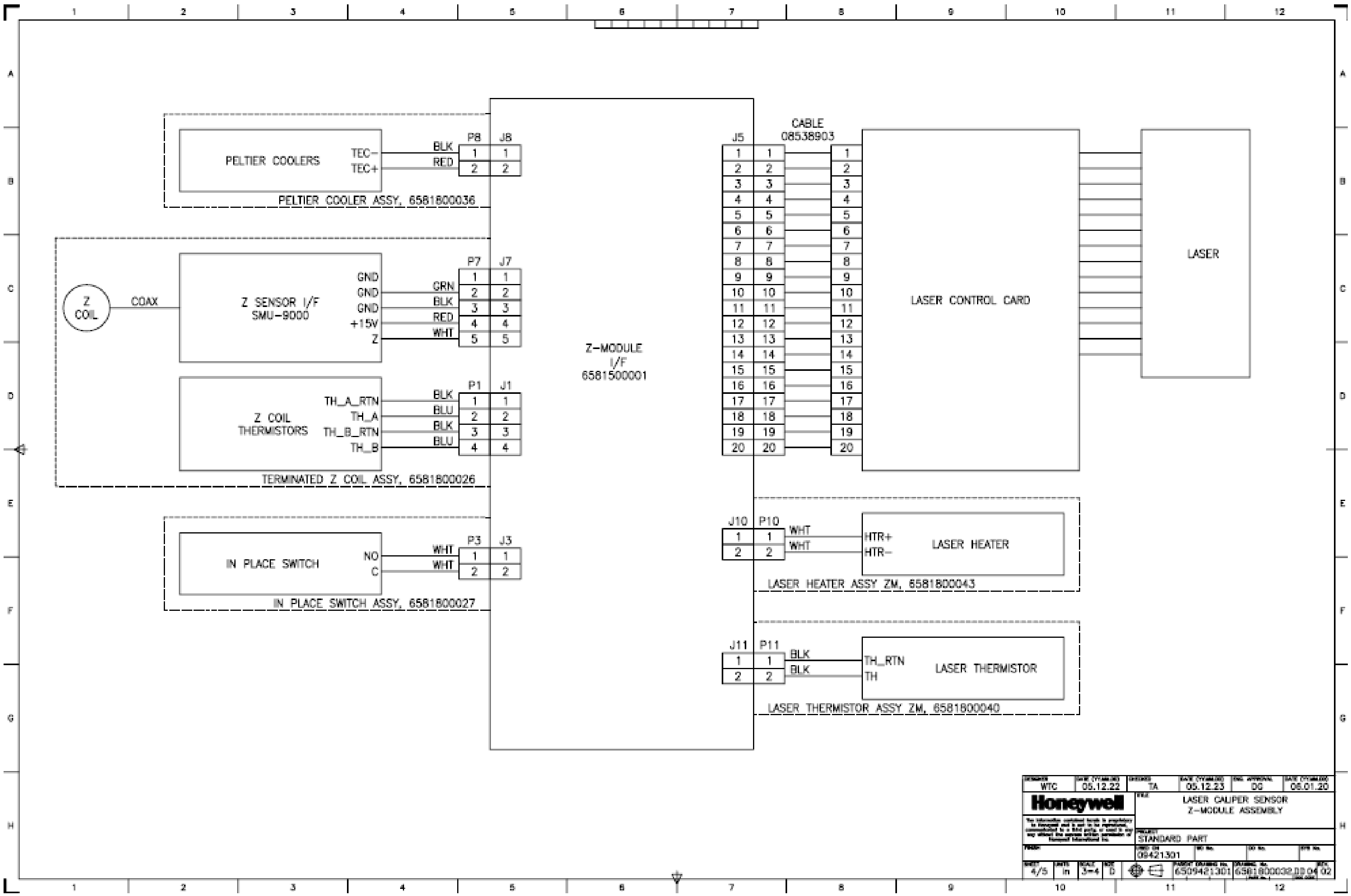

Figure 9-11 6581800032: laser caliper sensor z-module assembly (4/5)

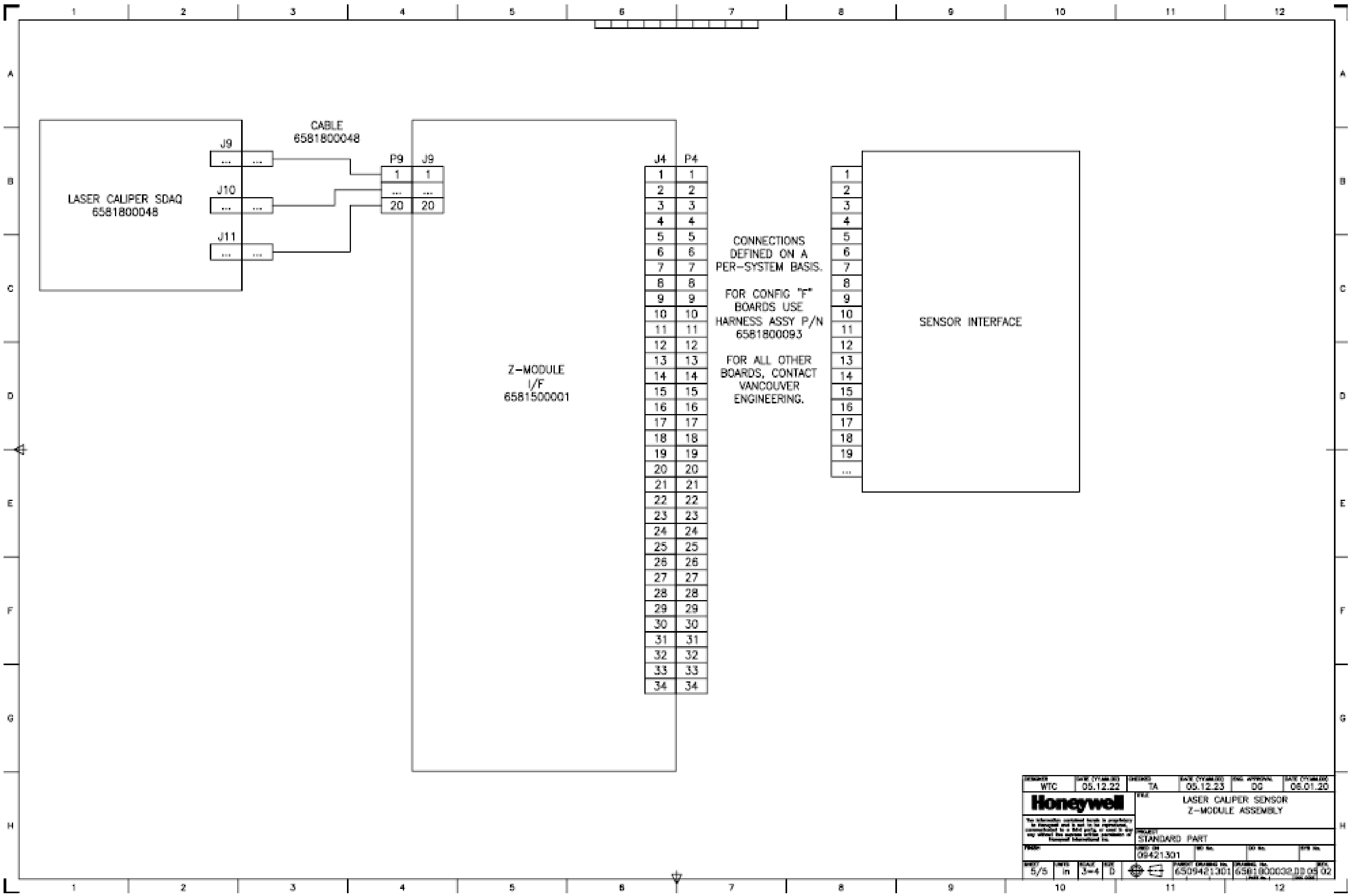

Figure 9-12 6581800032: laser caliper sensor z-module assembly (5/5)

Table 9-1 SP09421301: Laser Caliper Spares List

ITEM	QTY	PART NUMBER
REGULATOR, MINI MANIFOLD MOUNT	2	6540130054
SWITCH,REED,MAGNETIC POSITION,50VA,15-20AT,W/CABLE	1	25000697
OCTAL BUFFER/LINE DRIVER, NON INVERTING	1	6542630042
STAGE, TRANSLATION MULTI-AXIS PRECISION	1	25000703
SLIDE TABLE, SINGLE AXIS	1	14000549
CYLINDER, AIR 5/16IN BORE 1 IN STROKE SS REAR PIVOT MNT PORTS 90 DEG ROTATED	1	6581100029
VACUUM GENERATOR, SMC 88KPA EXH	1	6581100017
PCBA LASER CALIPER, I/F Z-MODULE	1	6581500001
PCBA LASER CALIPER, I/F CAL-MODULE	1	6581500002
PCBA, SDAQ MODIFIED FOR LASER CAL	2	6581500013
SENSOR ASSY, TERMINATED Z LASER CAL	1	6581800026
SWITCH ASSY, IN PLACE LASER CAL	1	6581800027
MOTOR ASSY, STEPPER LASER CAL	1	6581800029
FLAG ASSEMBLY, LASER CAL	1	6581800138
FLAG SOLENOID ASSY, LASER CAL	1	6581800035
THERMOELECTRIC COOLER ASSY, LASER CAL	1	6581800036
THERMISTOR ASSY, UPPER LASER CAL	1	6581800040
THERMISTOR ASSY, LOWER LASER CAL	1	6581800041
HEATER ASSY, UPPER LASER CAL	1	6581800043
HEATER ASSY, LOWER LASER CAL	1	6581800044
LASER ASSY, Z-MODULE LASER CAL	1	6581800052
LASER ASSY, CAL-MODULE LASER CAL	1	6581800053
DOME ASSEMBLY, LOWER, LCAL SENSOR	1	6581800062
LASER DRIVER CARD, LCAL	1	6581500029

10. Glossary

Actuator	Mechanical or electronic device that performs the control action in a control loop.
Back Side	See **Drive Side**.
Bin	The smallest measurement zone on the frame. Also called **Bucket** or **Slice**.
Bucket	See **Bin**.
Cable End	Location of the electronics and/or the entry point for communications and power on the scanner.
CD	**Cross Direction** Used to refer to those properties of a process measurement or control device that are determined by its position along a line that runs across the paper machine. The Cross Direction is transverse to the MD (Machine Direction) that relates to a position along the length of the paper machine.
CD Spread	Variation in the profile data equal to twice the standard deviation of the measured variable.
CML	Calibration-module laser
Code	See **Recipe**.
Da Vinci	A Quality Control System.
Distant End	The end of the scanner opposite the Cable End.

Drive Side (DS)	The side of the paper machine where the main motor drives are located. Cabling is routed from this end. Also called **Back Side**.
Foreign Controller	The controller for a foreign non-Honeywell CD actuator, e.g., a Voith dilution profiling headbox.
Front Side	See **Tending Side**.
GSP	Gauge Support Processor
HMI	**Human Machine Interface**
High End Calibrate Distance	The distance from a fixed point on the sensor head to the closest vertical member of the scanner when it is located at the High End Limit Switch. This position is determined during scanner calibration.
High End Calibrate Position	The value of the head position when the sensor head reaches the High End Calibration Position. This is only updated during a scanner calibration procedure.
Integrated PMP	Precision Measurement Processor integrated onto the scanner (4000-00 Model).
LVDT	Linear Variable Displacement Transducer. Used to provide an accurate displacement reference.
MD	**Machine Direction**
	The direction in which paper travels down the paper machine.
Low End Calibrate Distance	The value of the head position (in millimeters) when the sensor head reaches the Low End Calibrate Position.
Low End Calibrate Position	This position is only updated during a scanner calibration procedure.
Low End Offset	The distance in millimeters from the Cable End of the scanner to where bucket zero is located.
MIS	**Management Information System**
	System or subsystem that collects and manages information on the paper production.

Measurement SubSystem	See **(PMP) Precision Measurement Processor**.
Motor End	Location of the motor on the scanner.
Motor End Support	Formed steel channel welded to the upper and lower box beams at the motor end.
MSS	**Measurement SubSystem**
MXOpen	Software Quality Control System. See **QCS**.
PMP	**Precision Measurement Processor** The computer and I/O enclosure that supports the motion control of the sensor head and the raw processing of the sensor voltages. Also known as the **MSS**. May be on the scanner end bell or in a separate remote enclosure.
PrecisionPak	A set of upper and lower heads mounted on the Precision Platform. The sensors are installed within the PrecisionPak, which travels back and forth on the rails of the Precision Platform.
Quality Manager	See **SSP.**
QCS	**Quality Control System** A computer system managing the quality of the paper produced.
RAE	**Real-Time Application Environment** The system software used by Da Vinci QCS to manage data exchange between applications (with Performance CD being one of them).
Recipe	A list of pulp chemicals, additives, and dyes blended together to make a particular grade of paper.
Remote PMP	Precision Measurement Processor remotely mounted.
RTDR	**Real-Time Data Repository** The database managed by RAE to store system data and data for individual applications.

Scan Position	A constant position (in millimeters) measured from the Cable End.
SSP	Scanner Support Processor.
SDP	Sensor Data Processor The computer in the system that performs system-level functions involving processing of inputs from other system computers, and outputs to the other system and plant computers connected to the plant Local Area Network.
Sensor Processor	A software program that takes one or many inputs from the PMP, converts those measurements to engineering units for measurement or measurement correction, performs automatic diagnostic tests, and reports on any alarm conditions.
Sensor Set	The term used in the Sensor Maintenance displays to describe a set of sensors working together on a scanner to perform one measurement.
Setpoint (SP)	Target value (desired value). Setpoints are defined process values that can be modified by entering new values through the monitor, loading grade data, and changing a supervisory target.
Slice	See **Bin.**
Smoothing Width	A value that determines the amount of averaging that will be applied to a measurement bin.
Standardize	An automatic periodic measurement of the primary and auxiliary sensors taken offsheet. The standardize measurements are used to adjust the primary sensors' readings to ensure accuracy.
Streak	A narrow cross-directional section of paper where a measured quality deviates significantly from the average of the entire width of the paper. or An area in an array of cross-directional measurements that deviates more than a certain amount from its surroundings. The amount of allowed deviation can be set up as an absolute number or as a percentage.

Target	A display area that is available for the user to make a selection or to enter data (RMPCT displays). or A numeric value that specifies a desired product quality.
Tending Side (TS)	The side of the paper machine where the operator has unobstructed access. Also called **Front Side**.
TEC	**Thermo-Electric Coolers** The TECs are located between the z-coil form and the feet of the translation plate. The translation plate feet act as a heat sink for the TECs. Thermistors are permanently embedded into the z-coil form and routed electrically to the z-module interface PCBA. Electronics on the interface PCBA actively supply current through the TECs so that the coil form temperature is fixed to 41°C.
TES	**Thermal Equalization System**
Trend	The display of data over time.
VIO	**Virtual Input/Output**
ZML	Z-module laser