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# DEFLECTION AND TWIST MEASUREMENT SYSTEM (DTMS) Model 47

## Features

- Results are not affected by the motion or acceleration of the structure being tested
- Three or five degrees of freedom are measured between two points without physical contact
- System accurately measures and reports deflection and twist in real time at multiple points along the structure:
  - Deflection accuracy, 0.2 mm
  - Twist accuracy, 0.1 degree
  - Frequency response, up to 100 Hz with continuous logging
- DTMS is scalable to match your individual test and measurement requirements
- All-digital design makes DTMS immune to noise and drift
- Software provides DTMS configuration, data logging to **.**CSV files, and three types of data plotting (3-D, strip-chart recorder, and time-history)
- Communication uses Modbus RTU protocol over RS485 network
- Power supply range from 12 to 48 VDC

## Potential Applications

- Automated assembly line instrumentation
- Permanent industrial metrology installations
- Wind turbine blades
- Vehicle frames
- Crane booms and other large machinery
- Boats, offshore rigs, and other marine equipment
- Aircraft wings and fuselages
- Helicopter rotors and tail booms

The Deflection and Twist Measurement System can accommodate a variety of structural shapes. It's ideal for applications where you can't use accelerometers or other ground-referenced instrumentation. Please contact Boxboro Systems to discuss your individual measurement needs:

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 Patent # 7403294 

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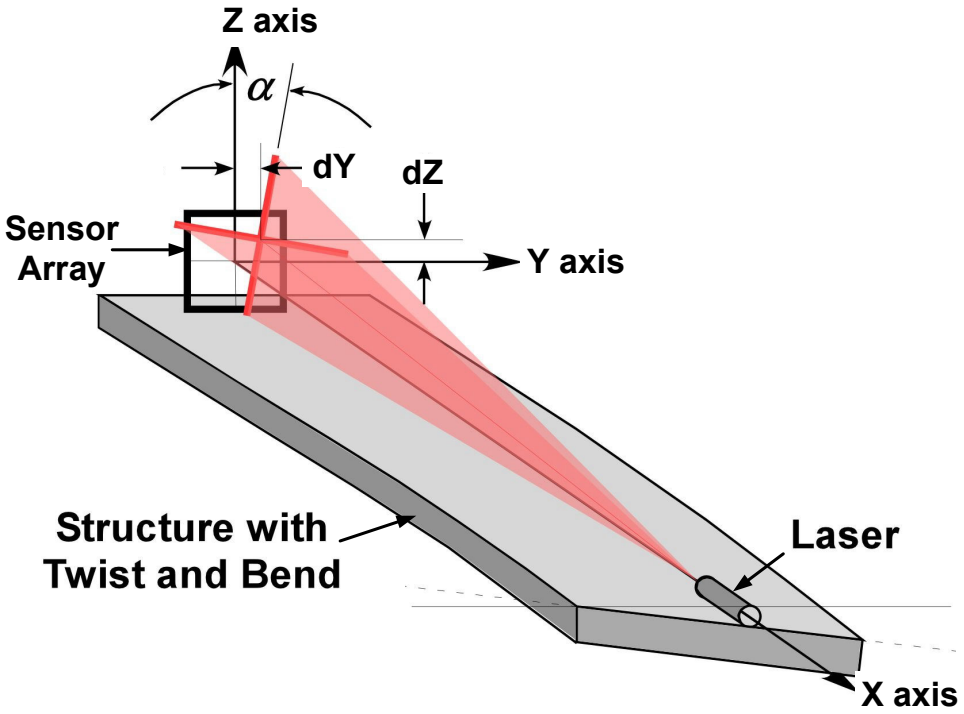
## General Description

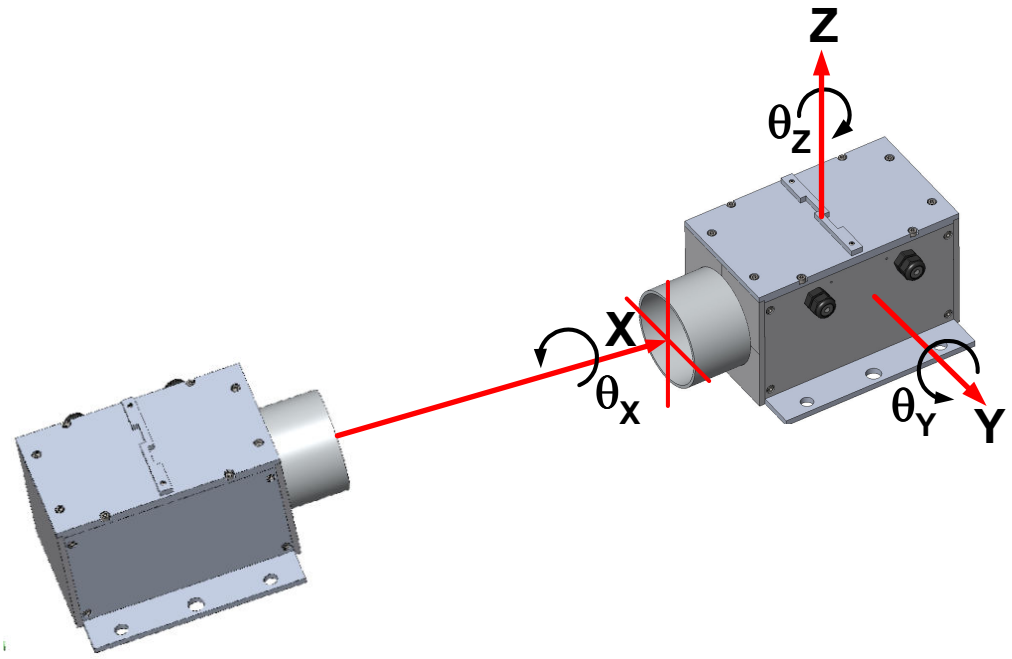
The simplest version of a DTMS system is called a half-segment (Figure 1). A laser projecting a cross-hair beam is rigidly mounted to one end of the structure being tested. A rectangular array of photosensors is rigidly mounted to the structure's other end. As the structure bends and twists, three types of motion are measured from one end of the structure to the other: side-to-side (dY), up-and-down (dZ), and twist about the X axis (α). In other words, the system reports three degrees of freedom.

**Figure 1. Half-Segment Schematic**




In a full-segment DTMS system, each end of the structure being tested has both a laser and a sensor array. With a full segment, the system reports five degrees of freedom by measuring five types of motion: deflection in the Y and Z directions and twist about the X, Y, and Z axes. Figure 2 shows the coordinate system for a DTMS module at one end of a full segment. The center of the coordinate system is half-way between the two ends of the enclosure and 66.5 mm up from the bottom of the base. For a half-segment system, the center of the coordinate system is 23 mm from the front face of the module (91 mm from the center of the module) and 66.5 mm up from the bottom of the base.

**Figure 2. Full-Segment Schematic with Coordinate System**




With these five degrees of freedom being reported, full segments can be placed end-to end to create a multi-segment system (Figure 3). The data from each segment is added vectorially – that is, the data from the end of each segment is reported with respect to the coordinate system of the beginning of the first segment, called the root module. (Either end can be selected as the root module for the data reference point.) The distance between the modules that make up each segment is set by the user to capture the maximum deflection within the segment. Shorter segments are used where the structure bends a lot, and longer segments are used in areas where bending is not as severe.

**Figure 3. Multi-Segment Schematic**

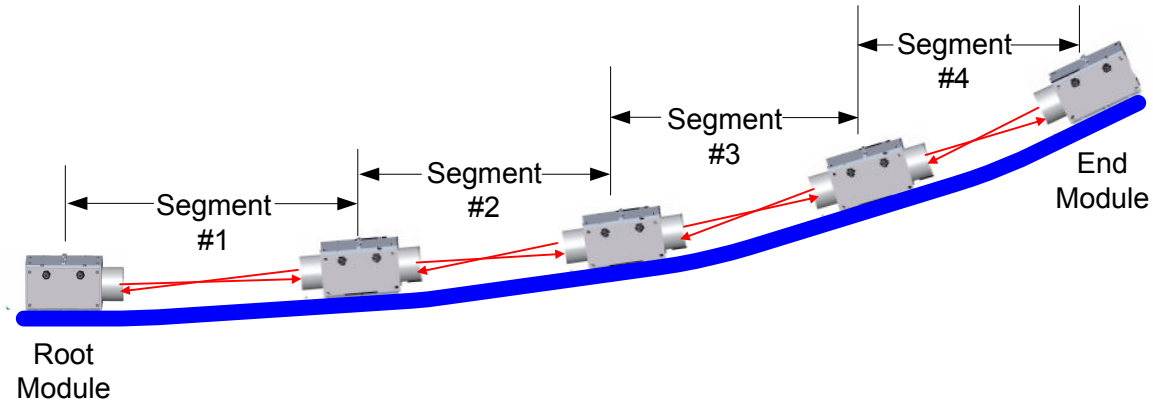



Figure 4 shows the maximum Y or Z deflections and curvature of the structure that can be measured with the DTMS Model 47. The length of the three measurement systems is the same (25 meters), but each has a different number of segments (5, 10, and 15) and thus different segment lengths. The symbols  show the locations of the sensor arrays. The graph was generated using the maximum data that can be measured (deflections within each segment and angle between segments).



**Figure 4. Maximum Deflections in Multi-Segment Systems**

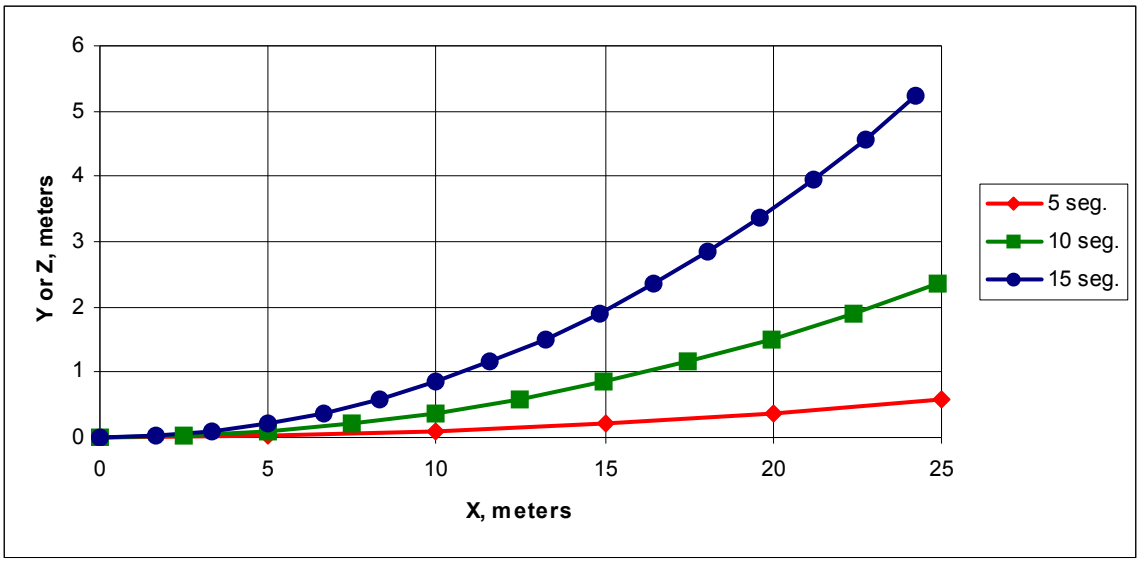
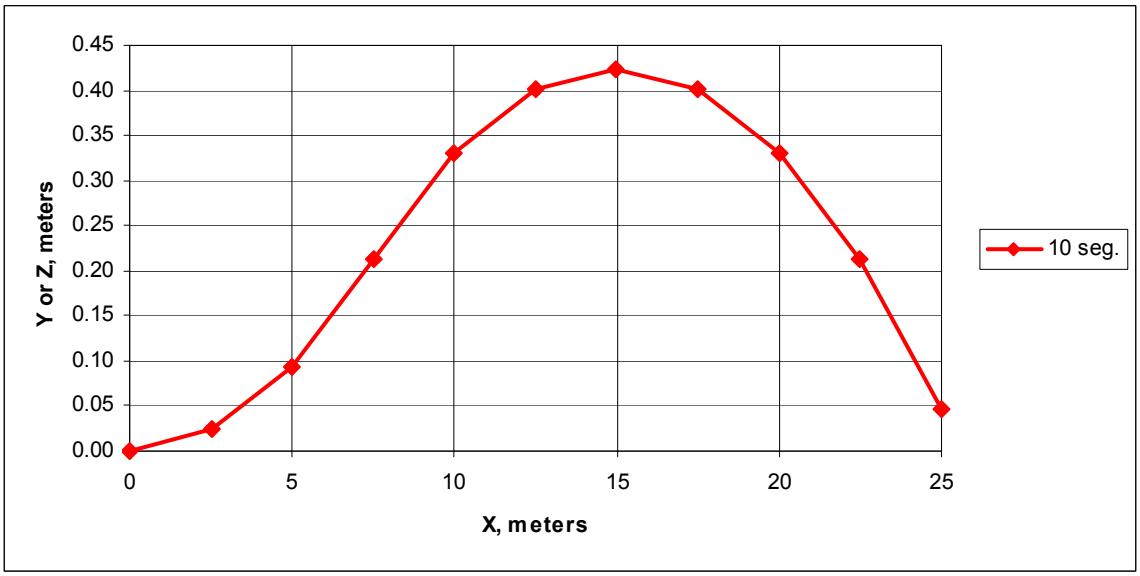



Figure 5 shows how a 25-meter system with 10 segments can measure the second-mode bending of a structure in the Y or Z directions.

**Figure 5. Second-Mode Bending in Multi-Segment Systems**

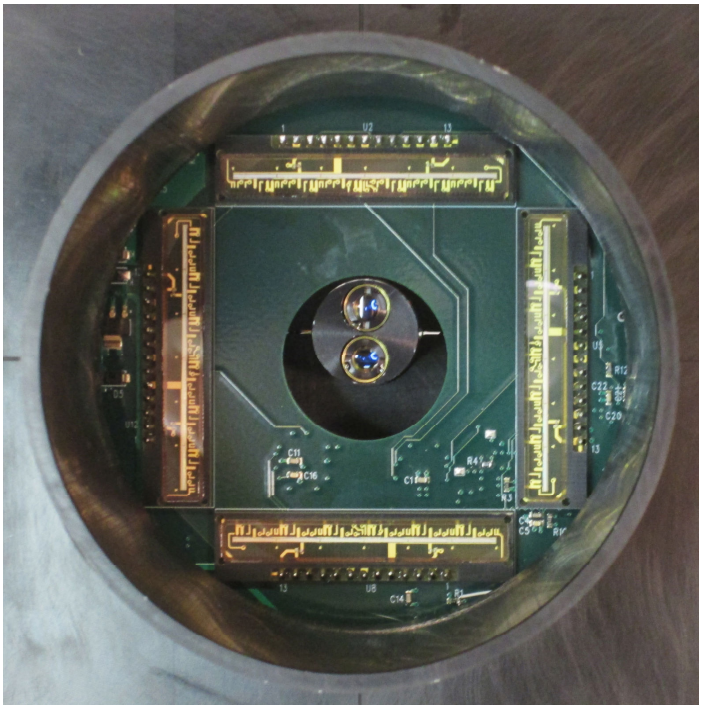



A DTMS Fitting Spreadsheet is available from Boxboro Systems. The spreadsheet allows you to enter the expected worst-case deformation of your structure and then select the number of segments and length of each segment that are required to ensure that an extreme deformation can be measured.

## DTMS Hardware

Figure 6 shows a Model 47 sensor array board, with four 47-mm-long CCD sensors (one on each side). The sensors have a resolution of 400 pixels per inch (a pixel spacing of 0.0025 inch or 0.0635 mm). The cross-hair laser can be seen through the hole in the center of the sensor array.

**Figure 6. Sensor Array Board**



The standard DTMS Model 47 enclosure (Figure 7), which is used in multi-segment systems, has lasers and sensor arrays at both ends. The root and end modules use the same enclosure, but with a laser and sensor array installed only at one end and a blank plate at the other end.

**Figure 7. Multi-Segment Enclosure**



All DTMS modules can be ordered with either fixed or adjustable laser mounts (Figures 8 and 9). The adjustable laser mounts are useful for structures with initial twist and bend. These mounts use 100 thread-per-inch adjustors and allow the laser beam to be aligned with the sensor array. The laser beam can be moved up/down and left/right, and it can be rotated. The adjustors can be locked when the laser is aligned.

**Figure 8. Fixed Laser Mounts**

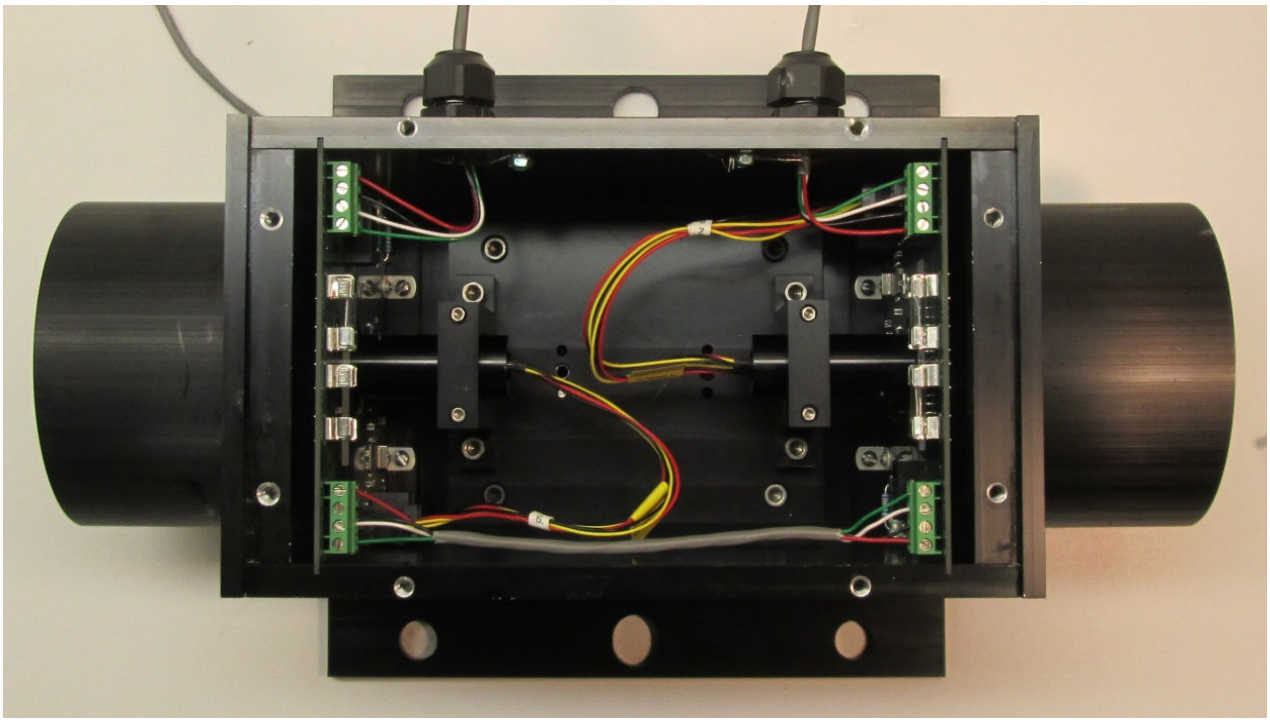




**Figure 9. Adjustable Laser Mounts (removed from enclosure)**

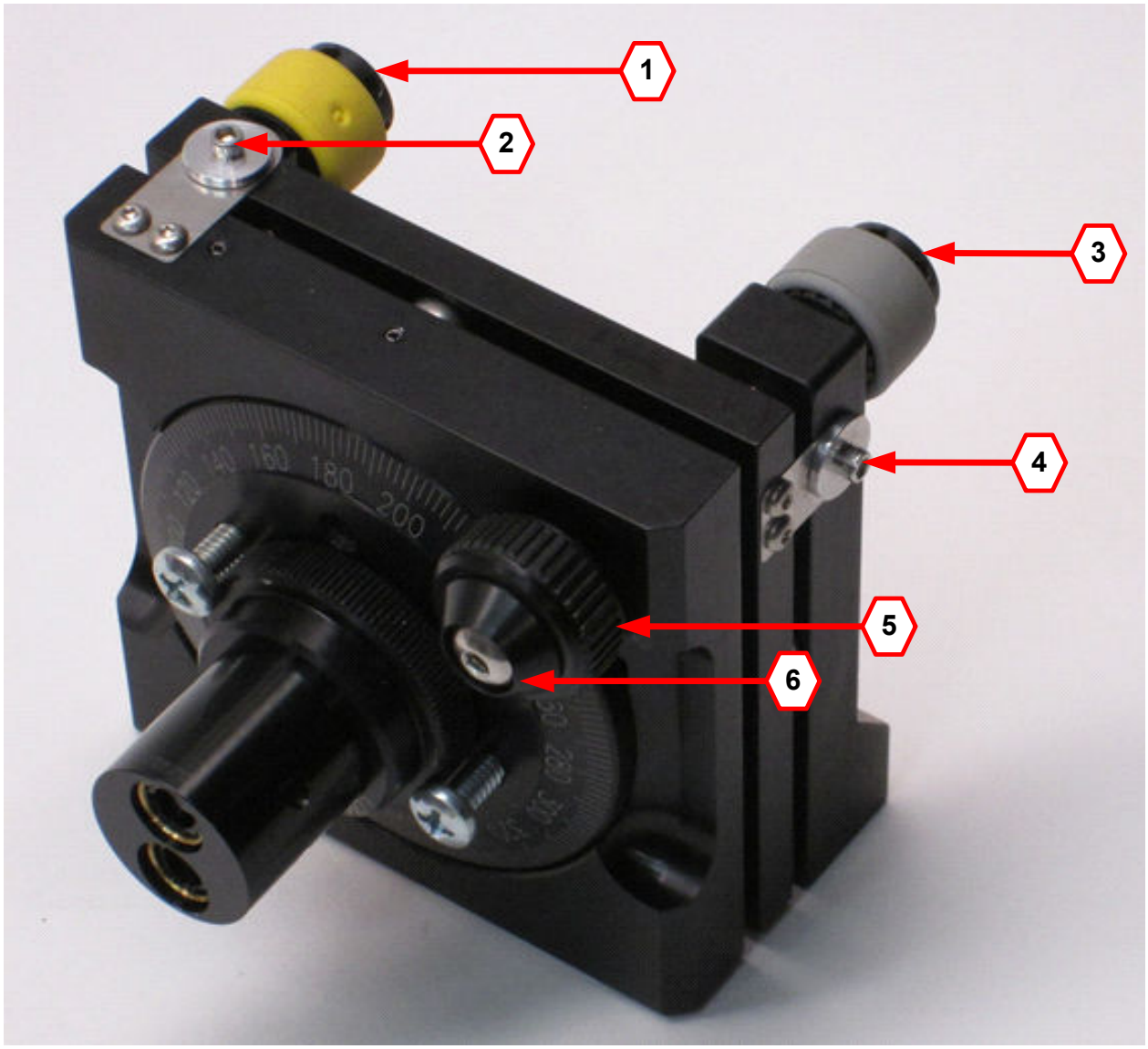



**Figure Key:**

The Yellow knob (**1**) moves the cross-hair from side to side, along the Y axis.

The side-to-side adjustment is locked in with the socket-head screw (**2**) using a 5/64 hex key wrench.

The Grey knob (**3**) moves the cross-hair up and down, along the Z axis.

The up-and-down adjustment is locked in with the socket-head screw (**4**) using a 5/64 hex key wrench.

The Black knob (**5**) rotates the cross-hair about the X axis.

The rotation adjustment is locked in with the button-head screw (**6**) using a 3/32 hex key wrench.

Note: Short L-type hex key 5/64 and 3/32 wrenches (stubby) are provided with the adjustable laser mounts to allow access to locking bolts 4 and 6 inside the DTMS case.

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## Detailed Specifications

Table 1 lists the maximum measurement ranges and other specifications for the DTMS Model 47. A simple estimate of the maximum deflection (D) that can be measured at the end of a multi-segment DTMS system is:

$$D = (\text{single-segment range}) \times (\text{number of segments})^2$$

As shown in Table 1, the DTMS Model 47 has a maximum Y or Z axis measurement range of +/–23.5 mm (or 0 to 47 mm). For a 10-segment string, the maximum deflection at the end of the string is approximately:

$$D = +/-23.5 \times 100 = +/-2350 \text{ mm}$$

For bending in only one direction, the maximum deflection is twice as large (D = 4700 mm).



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**Table 1. DTMS Model 47 Specifications**

| | Metric | English |
|---|---|---|
| Sensor array size | 47 x 47 mm | 1.85 x 1.85 inch |
| Half-segment or full-segment maximum measurement range, Y or Z direction [a] | +/–23.5 mm or 0 to 47 mm | +/–0.925 inch or 0 to 1.85 inch |
| Frequency response | up to 100 Hz | |
| Maximum twist about X per segment [b] | 35 degrees | |
| Maximum twist about Y or Z [c] | depends on segment length | |
| Maximum segment length [d] | 45 meters | 150 feet |
| Minimum segment length (standard laser) | 1.2 meters | 4 feet |
| Minimum segment length (wide fan angle) | 0 meters | 0 feet |
| Half-segment worst-case deflection error | 0.2 mm | 0.008 inch |
| Half-segment worst-case twist error | 0.1 degree | |
| Multi-segment worst-case deflection error (Y or Z) [c] versus number of segments (N) | (1.1 x N) – 0.5 mm | (0.0433 x N) – 0.0197 inch |
| Multi-segment worst-case twist error ($\theta_X$, $\theta_Y$, $\theta_Z$) [c] | (0.031 x N) – 0.0197 degrees | |
| Module size, length x width x height [e] | 228.6 x 133.4 x 139.7 mm | 9 x 5.25 x 5.5 inches |
| Module weight | 5.85 kg | 12 lb 14.5 oz |
| Pipe adaptor length | 91.4 mm | 3.6 inches |
| Power supply voltage | 12-48 VDC | |
| Maximum power draw | 3 Watts/segment | |
| Communication | 2-wire RS485, up to 1M bits per second | |
| Communications protocol [f] | Modbus RTU | |
| Maximum number of segments | 127 | |
| Operating temperature | –10º to 50ºC | 14º to 122ºF |
| Storage temperature | –40º to 80ºC | –40º to 176ºF |
| Humidity | 0% to 90% RH (non-condensing) | |
| Laser mounts | fixed or adjustable | |
| Laser boresight stability | 10 micro-radians/ºC | |

a The laser's "zero" position can be adjusted anywhere within the rectangular sensor array. Data shown is for lasers set to the center (bi-directional measurement) and to one edge (uni-directional measurement).

b Maximum twist is at zero Y or Z axis deflection. See the fitting spreadsheet for the maximum twist measurement with Y and/or Z deflections.

c See Table 2 for details.

d Maximum distance between end points. The 45-meter length can be extended to meet your requirements (please contact Boxboro Systems).

e Length is along the X axis, width is along the Y axis, height is along the Z axis.

f Other communications protocols can be accommodated.

The twist about the Y or Z axis is the tangent angle between adjacent segments. The twist about the X axis is the cumulative twist up to and including the current segment. Table 2 shows the maximum deflection and twist errors for DTMS systems with up to 10 segments.

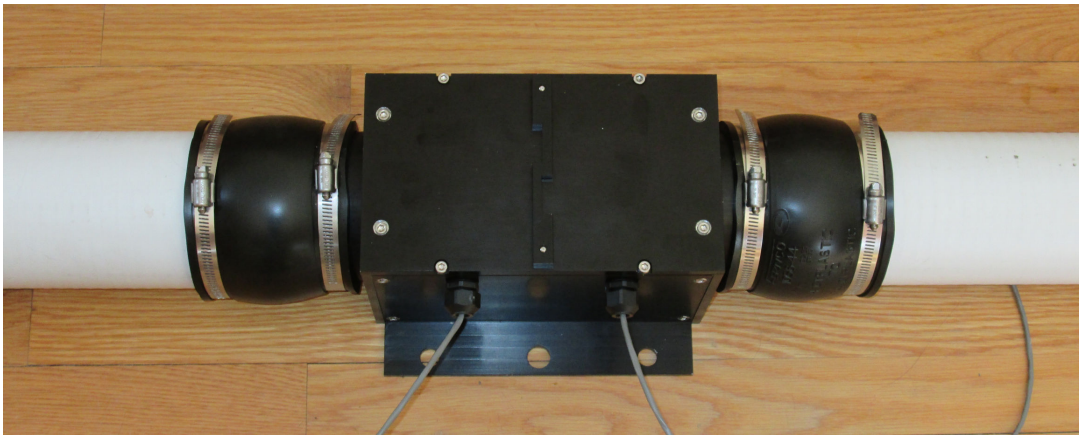
**Table 2. Worst-Case Deflection and Twist Errors vs. Number of Segments**

| Number of Segments | Deflection Errors (Y, Z) | | Twist Errors ($\theta_X$, $\theta_Y$, $\theta_Z$), degrees |
|---|---|---|---|
| | mm | inch | |
| 1 | 0.6 | 0.024 | 0.077 |
| 2 | 1.7 | 0.067 | 0.108 |
| 3 | 2.8 | 0.110 | 0.139 |
| 4 | 3.9 | 0.154 | 0.170 |
| 5 | 5.0 | 0.197 | 0.201 |
| 6 | 6.1 | 0.240 | 0.232 |
| 7 | 7.2 | 0.283 | 0.263 |
| 8 | 8.3 | 0.327 | 0.294 |
| 9 | 9.4 | 0.370 | 0.325 |
| 10 | 10.5 | 0.413 | 0.356 |

## DTMS Options

- Plastic pipe for protecting the optical path in set-ups that will be exposed to dirt, rain, and bright lights (Figure 10). Pipe adaptors and 4-inch rubber couplings can be provided. We recommend using lightweight 4-inch HDPE triple-wall drain pipe, which has a non-reflective internal lining and is available at building supply stores in 10-foot lengths. The HDPE drain pipe is 4.215 inches in diameter (10.71 cm), and the pipe is connected to the DTMS modules with standard 4-inch rubber pipe couplings, such as FERNCO model 1056-44, which will accept pipe diameters from 4 to 4.65 inches (10 to 11.8 cm).

**Figure 10. Triple-Wall Drain Pipe on Either Side of DTMS Module**



- For a PC to communicate with the DTMS, an RS485 two-wire adaptor is needed. You can purchase a B&B Electronics USOPTL4 Isolated USB-to-RS485 port-powered converter through Boxboro Systems.

- You can purchase a Tenma Model 72-8345 lab-style power supply through Boxboro Systems as an option. It can supply up to 36 VDC at 3 amps (108 Watts) and has current-limiting to prevent damage from short circuits. The Tenma supply also displays the voltage and current. It has banana jacks for +V, –V, and earth ground.

- For DTMS power and communications. Boxboro Systems can provide 22-gauge, four-conductor (two pair), twisted shield cable.

- An optional pressure and temperature transducer is available which allows the DTMS program to display the board's ambient pressure in psi (pounds per square inch) and the temperature in degrees Celsius. (If the transducer is not installed, these fields display N/A.)

## DTMS Software

Boxboro Systems provides the PC software for setting up a DTMS system and logging the data from it. This software features the following capabilities:

- Data logging
  - Selectable sample rate
  - Data stored in **.**CSV format for review in spreadsheet or other analysis programs
- Data plotting
  - 3-D plot (during acquisition or review)
  - Chart recorder plot (during acquisition only)
  - Time history (during review only)
- Set-up
  - Laser signal strength
  - Laser cross-hair display
- Configuration
  - Number of segments, lengths, and Modbus addresses
  - Saving of named configurations
  - Collection of zero data

Figures 11-16 show computer screen images that illustrate the DTMS software capabilities. For OEM applications, where the displacement data is used for monitoring and control, the functions of the host computer can be programmed into an existing controller. Please refer to the DTMS Model 47 User Manual for more information on the software.

**Figure 11. 3-D Plot**

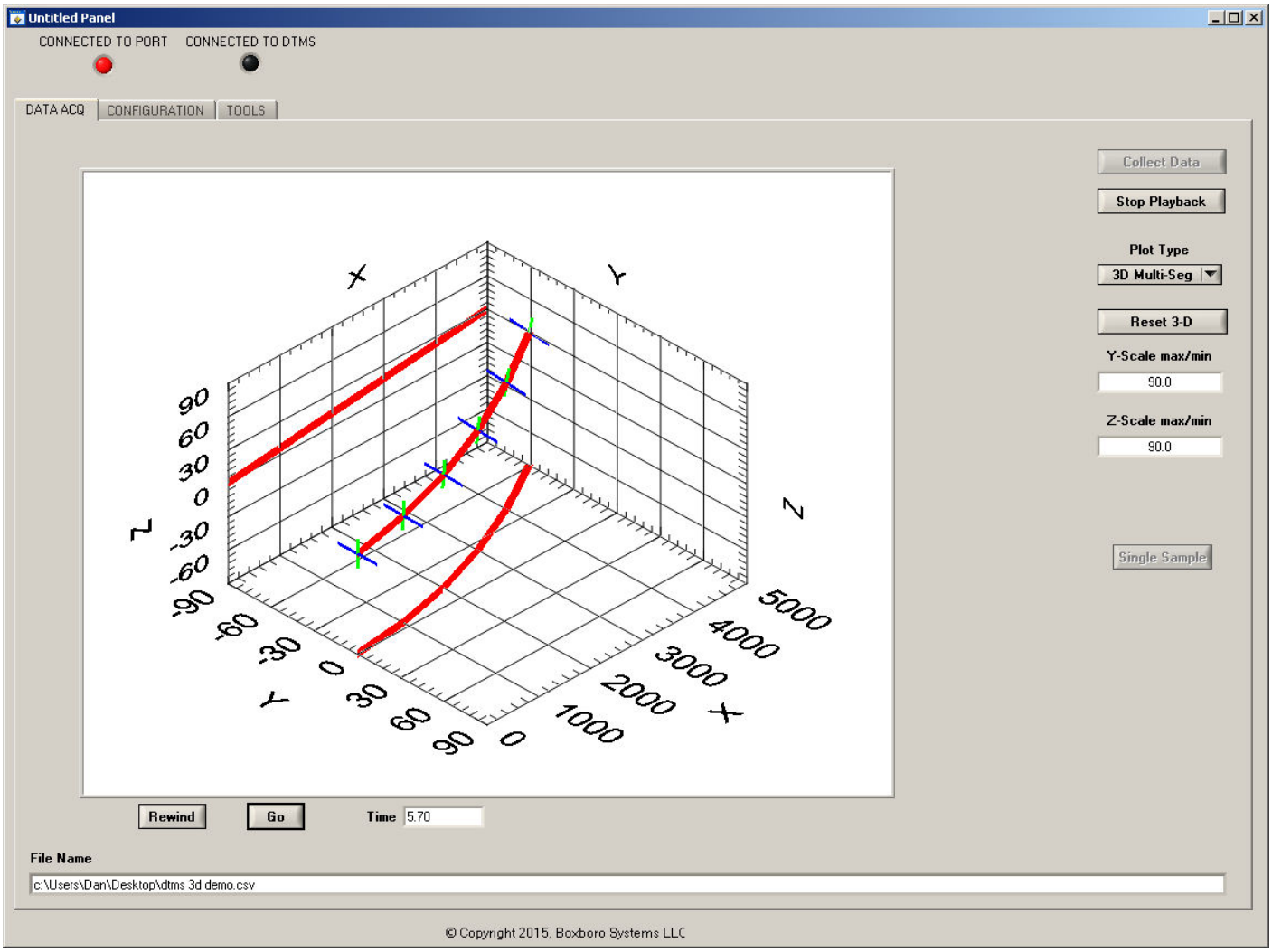


**Figure 12. Time History**

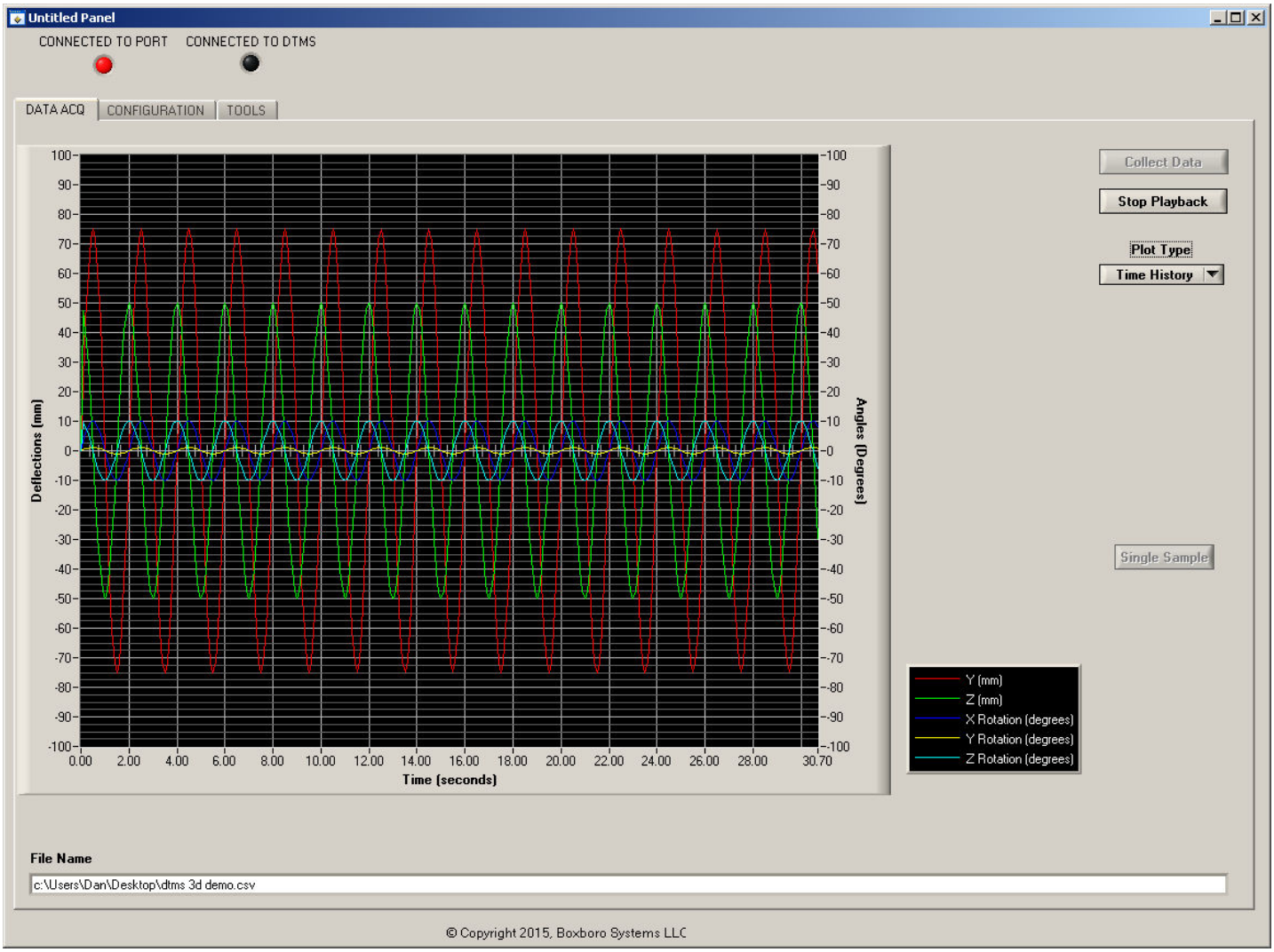


**Figure 13. System Configuration**

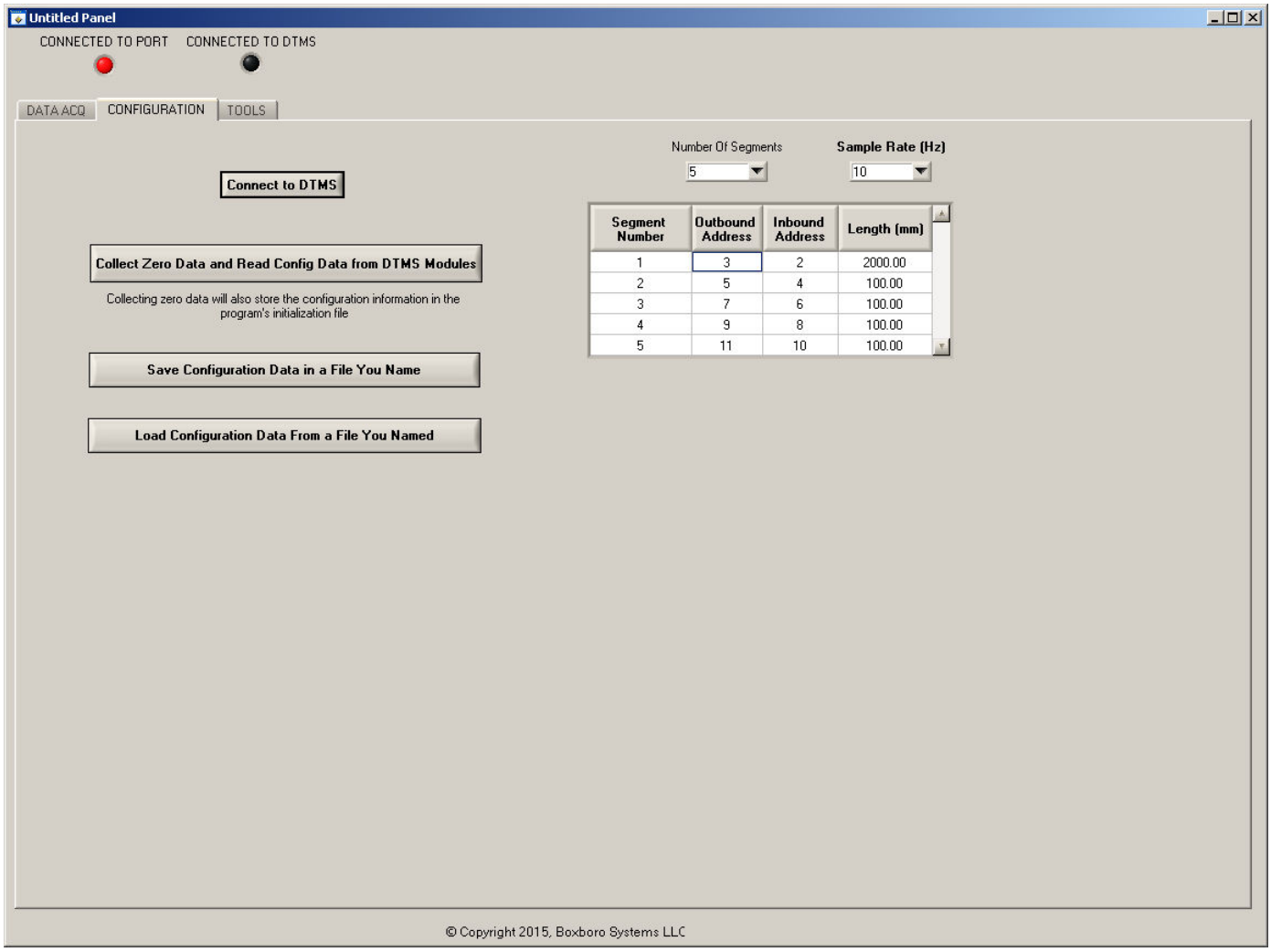




**Figure 14. Communications Set-Up**

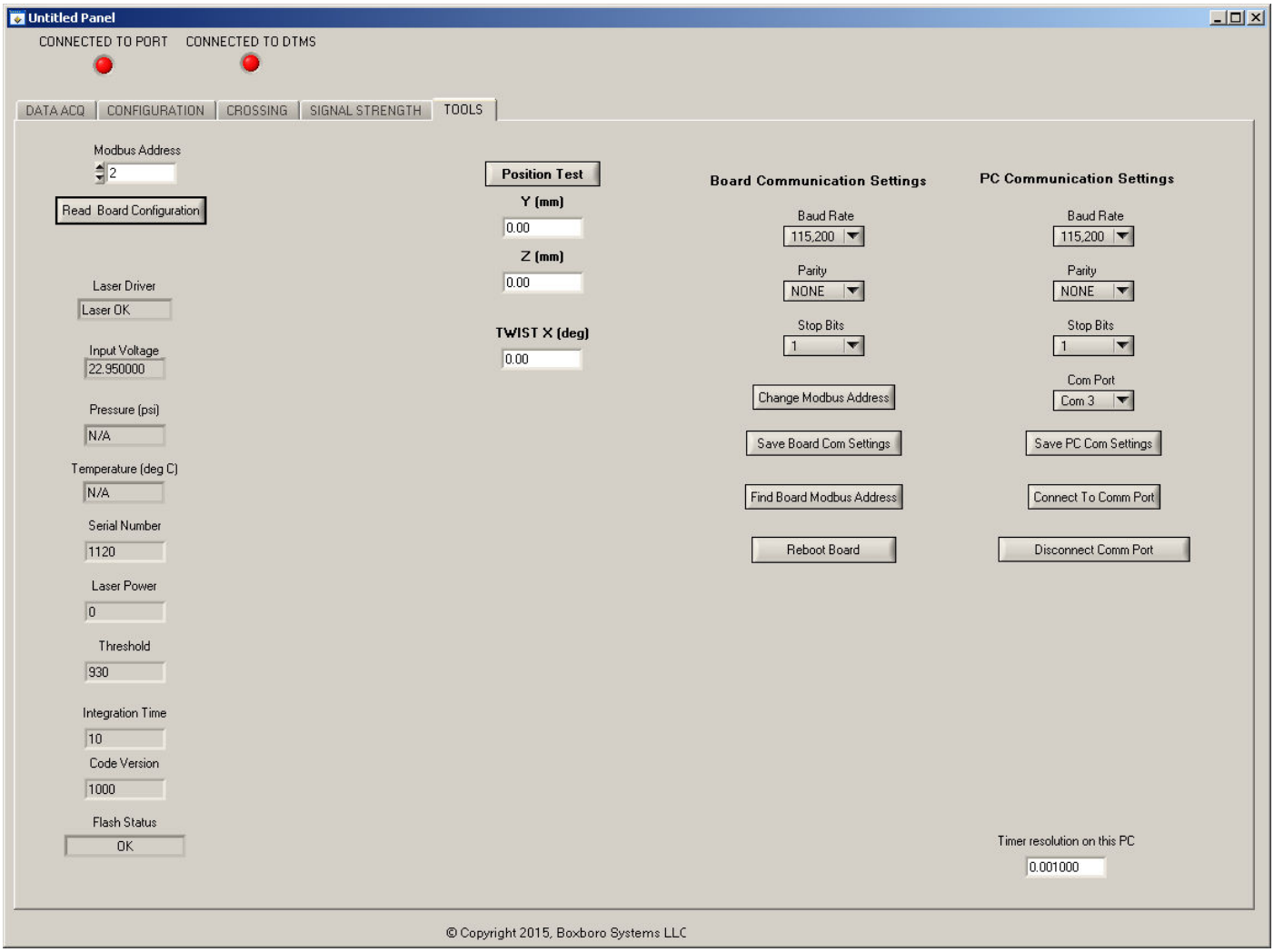


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**Figure 15. Laser Signal Strength**

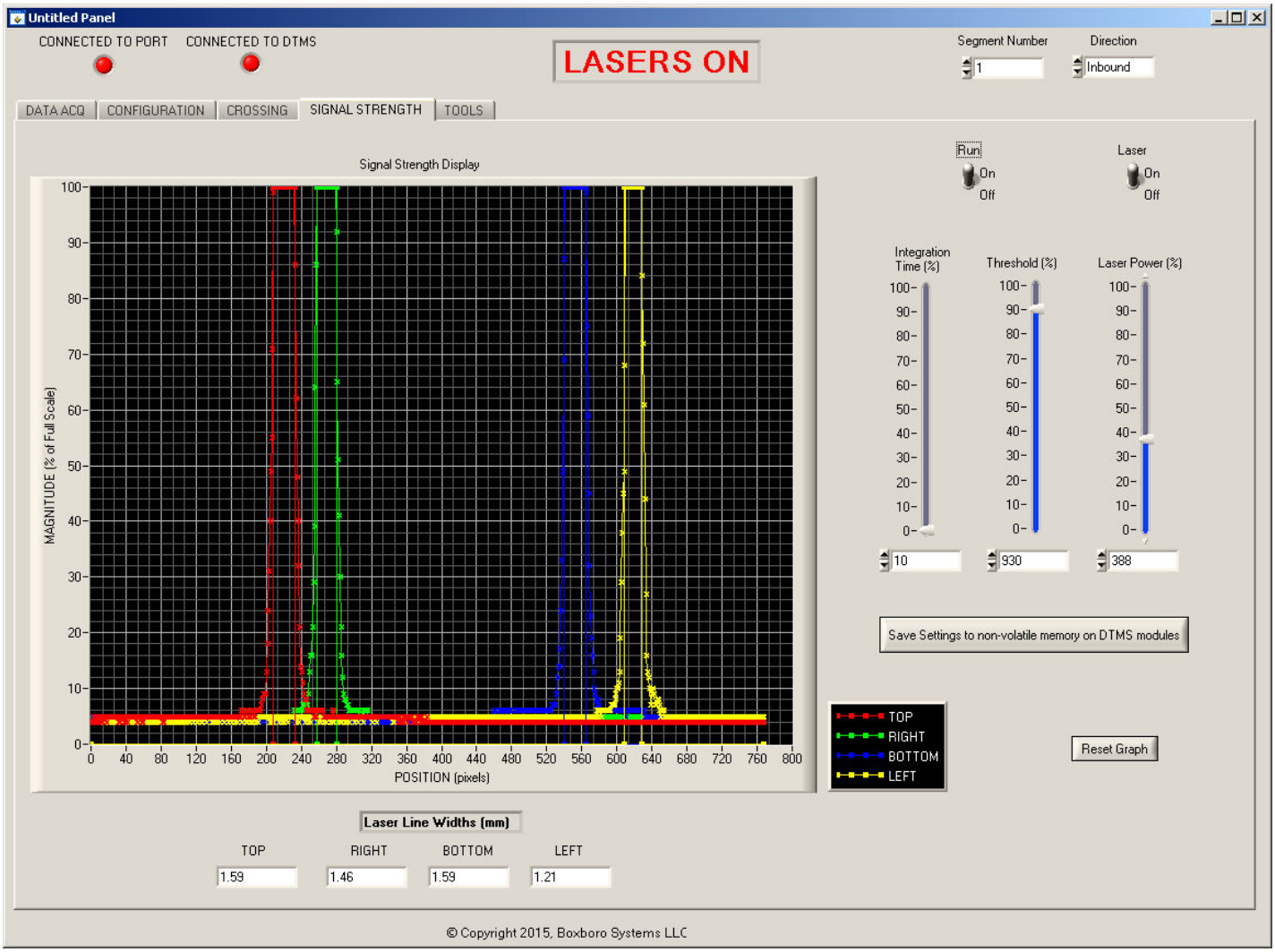
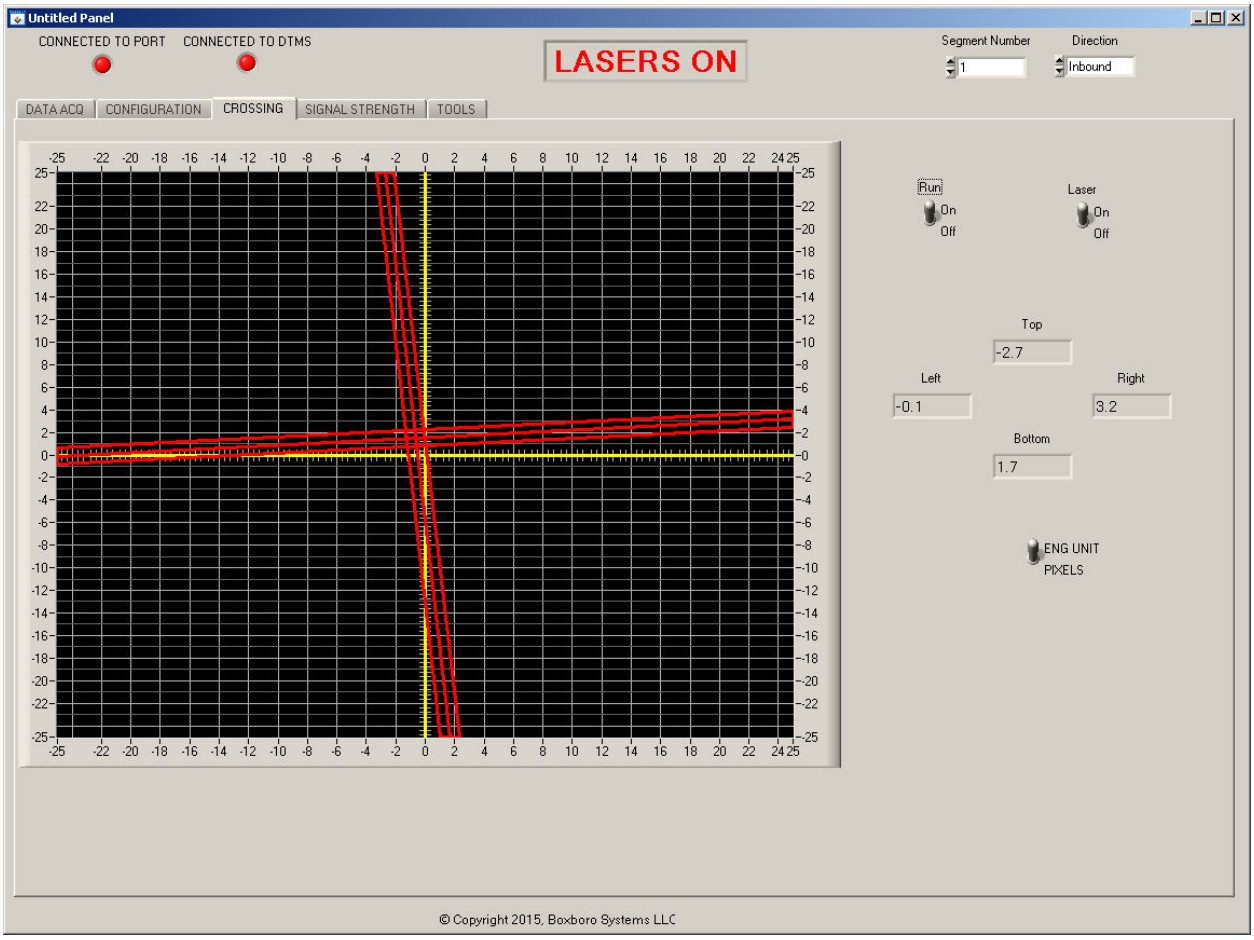


**Figure 16. Laser Cross-Hair Display**



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## Ordering Information

The DTMS Model 47 is ordered in the following format:

**Model 47 – Segment type – Module type – Laser mount type – Laser or Sensor array**

The following letters are used to create part codes in this ordering format:

Segment type
- H = Half segment
- F = Full segment

Module type
- E = End module
- M = Middle module

Laser mount type
- A = Adjustable mounts
- F = Fixed mounts

Laser or sensor array (applies only to half-segments)
- L = Laser only
- S = Sensor array only

EXAMPLES

Half-segment system:

| Quantity | Code | Description |
|---|---|---|
| 1 | H – E – A – L | Half-segment End module with Adjustable-mount Laser (no sensor array) |
| 1 | H – E – S | Half-segment End module with Sensor array (no laser) |

Full-segment system with fixed laser mounts:

| Quantity | Code | Description |
|---|---|---|
| 2 | F – E – F | Full-segment End modules with Fixed-mount lasers and sensor arrays |

Multi-segment system (five modules) with adjustable laser mounts:

| Quantity | Code | Description |
|---|---|---|
| 2 | F – E – A | Full-segment End modules with Adjustable-mount lasers and sensor arrays |
| 3 | F – M – A | Full-segment Middle modules with Adjustable-mount lasers and sensor arrays |

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**For more information on the DTMS,**
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