



LUNA

Using the Luna ODiSI: High-Density Strain and Temperature Data Improves Testing and Process Monitoring

Aida Rahim, PhD
Senior Applications Engineer

Presenter

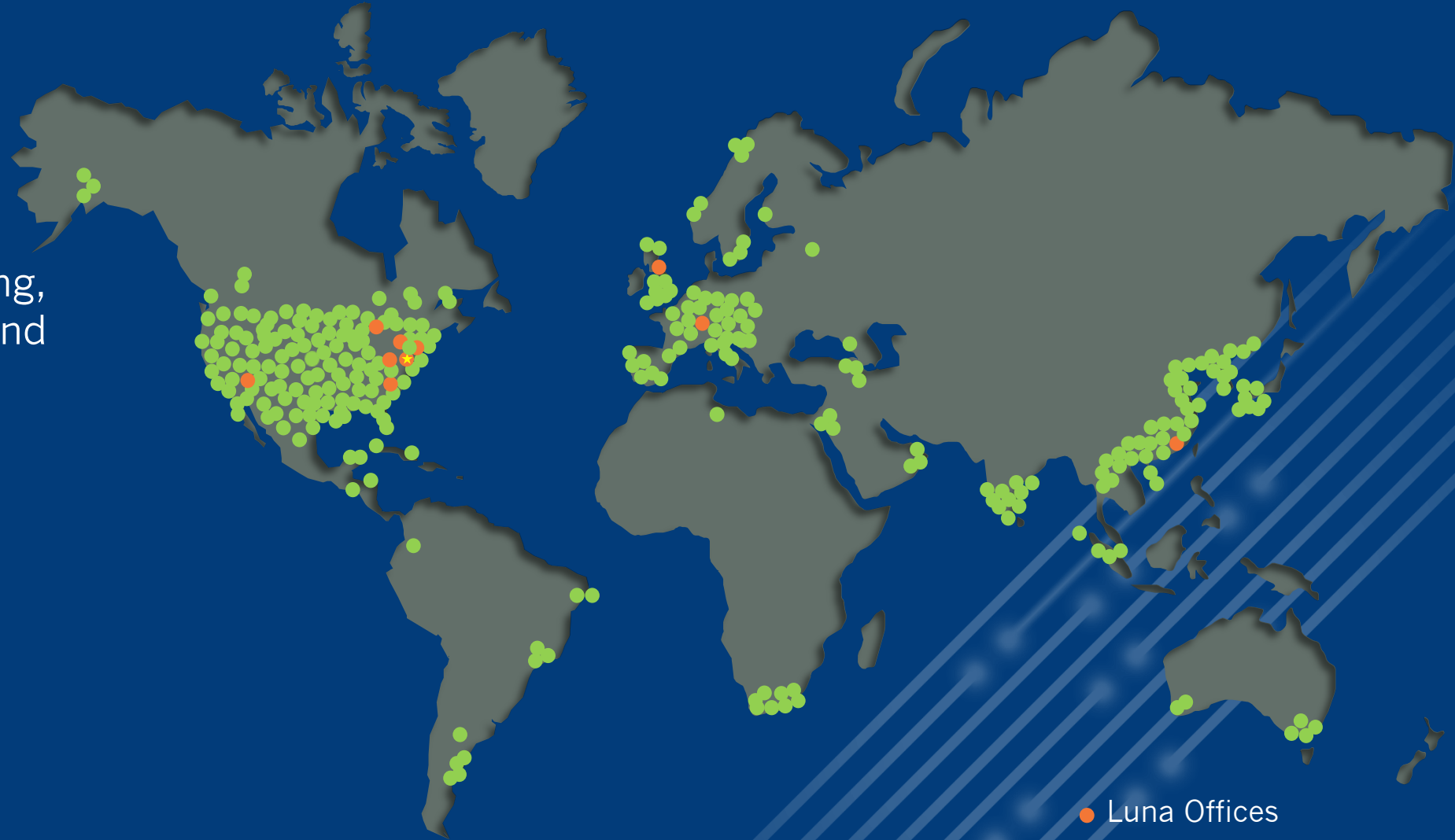
- PhD Mechanical Engineering from MIT
- Part of the Luna team since 2011
- Projects:
 - New sensor design, testing, and validation
 - Temperature monitoring of battery packs
 - Embedding sensors in composites for structural testing
- Supports:
 - Customer training and applications
 - Product testing



Aida Rahim
Senior Applications Engineer

Luna Innovations

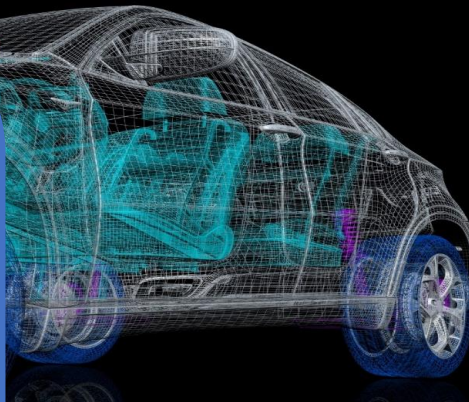
- Founded 1990
- NASDAQ: LUNA
- Fiber-optic-based sensing, measurement, testing and control products for:
 - Aerospace & Defense
 - Automotive
 - Communications
 - Infrastructure
 - Process control
 - Security
 - Silicon photonics
 - Transportation



- Luna Offices
- Customer sites

Mission: Enhance the safety, security and connectivity of people...

Sensing & Non- Destructive Test



Aerospace, Automotive, Infrastructure Safety & Security, Process Control

- Enabling next generation designs in aerospace and automotive through through better measurement
- Protecting infrastructure and perimeters through smarter sensors and systems
- Enhancing process control & non-destructive testing (NDT) with Terahertz technology

Comms Test & Photonic Controls



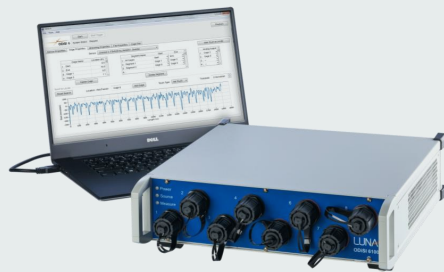
Communications and Defense

- Enabling next generation high speed optical networking through faster, better measurements
- Enhancing optical systems and instruments through high quality, precise control of light

Luna Innovations Portfolio

Sensing

Measurement Systems and Sensors



ODiSI



T-Ray

HYPERION



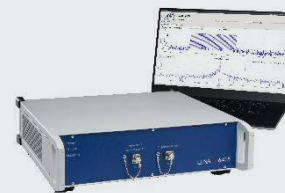
HYPERION
PLATFORM



Sensors

Photonic Test, Measurement & Control

Optical Measurement and Control Systems



Luna 6415



OVA



OBR



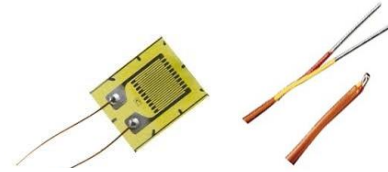
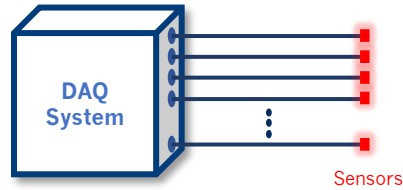
Polarization Measurement and Control

Lasers, Filters, Polarization Modules, Delay Lines, Detectors, etc.



Standard Electrical Sensing

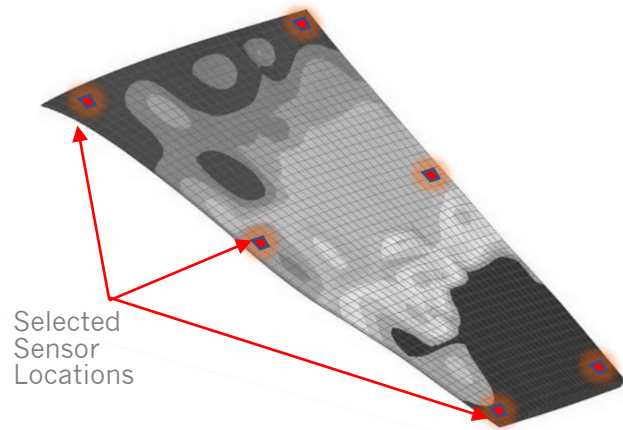
Multiple Copper Wires Per Sensor



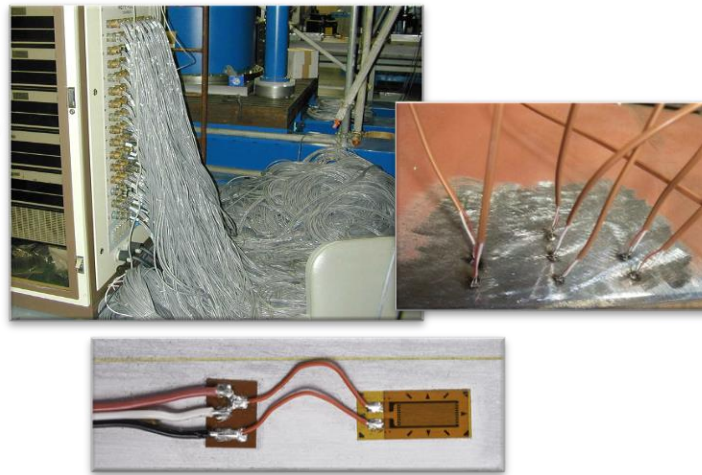
Foil strain gages, thermocouples, RTDs, etc.

- 2-3+ wires per sensor
- Multiple DAQs
- Low resolution
- Bulky, metallic wiring

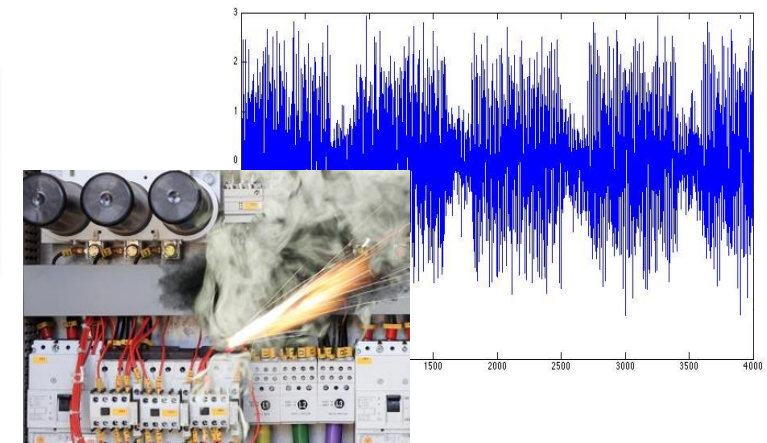
Limited Data
(Low Sensor Count)



Bulky Sensors and Cabling

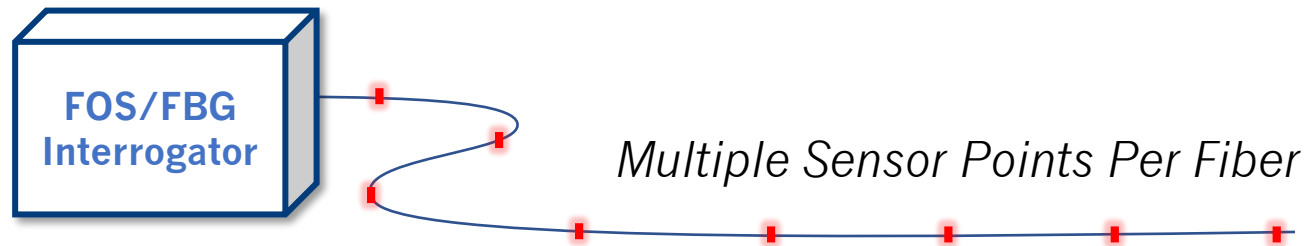


Susceptible to
Electromagnetic
Interference



Fiber Optic Sensing

High-Speed Distributed Sensing



- Single optical fiber
- Static and dynamic measurements
- Long range (km's)
- Easy to install

High-Definition Distributed Sensing



- Single optical fiber
- 1000's of sensors
- Ultra-high spatial resolution
- Easy to install

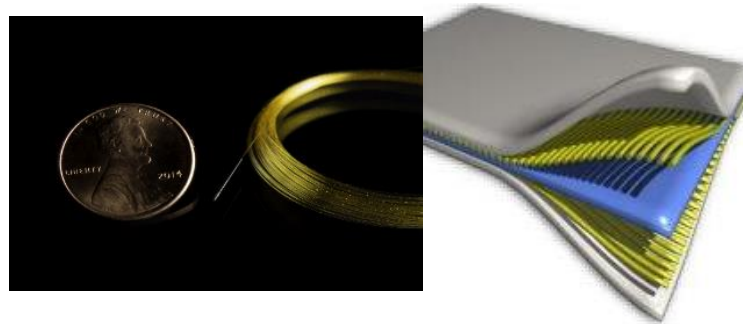
Fiber Optic Sensor Advantages

Works in harshest environments



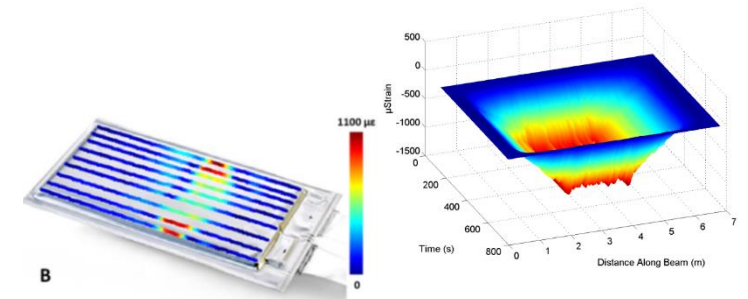
- Passive
- Immune to EMI
- Chemically inert
- Intrinsically safe

Can measure *where* you need data



- Very small, low profile (easy to embed)
- Lightweight
- Flexible
- Distributed

Provides more data, more insight



- High-definition mapping of strain/temperature
- Distributed sensing over large areas

Optical Distributed Sensor Interrogator (ODiSI)

- High-definition fiber optic sensing (HD-FOS) for strain and temperature

- Ultra-high spatial resolution

- Gage pitch (spacing) down to 0.65mm
- >1,500 sensor locations per meter of fiber

- Multi-channel system

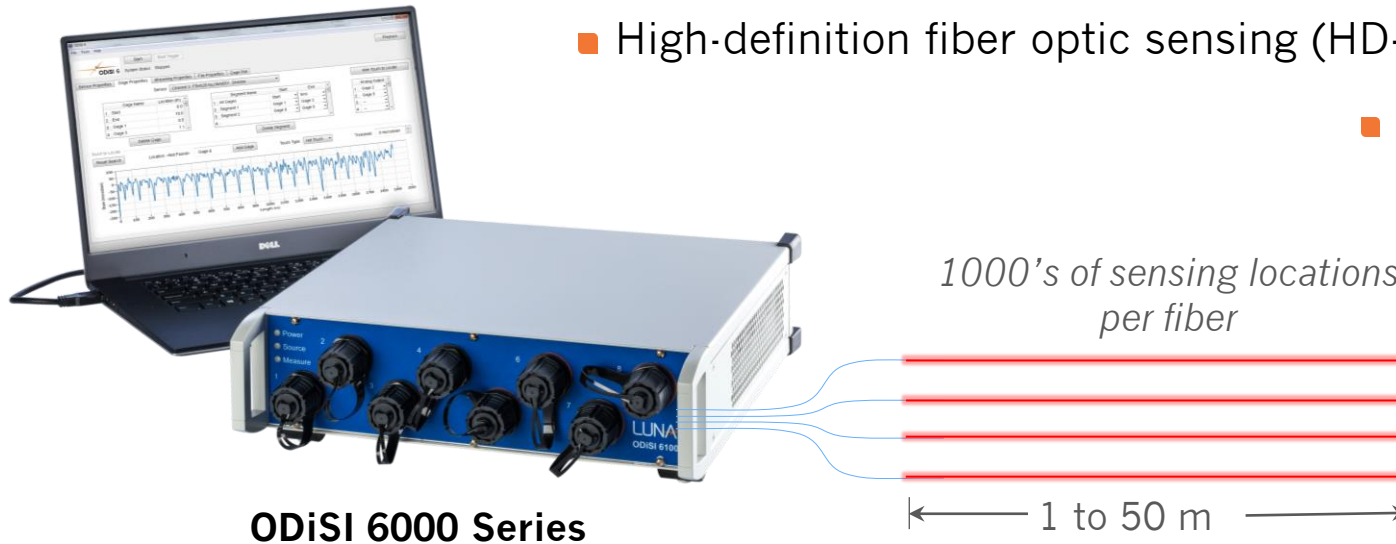
- 1, 2, 4 or 8 HD-FOS sensor channels
- Sensors up to 50 m in length each

- NIST-traceable strain measurements

- Network connectivity with IEEE 1588 PTP

- Easy-to-use software

- Sensor/gage configuration and management
- Acquisition and data logging
- Real-time 2D and 3D visualization software



Sensors

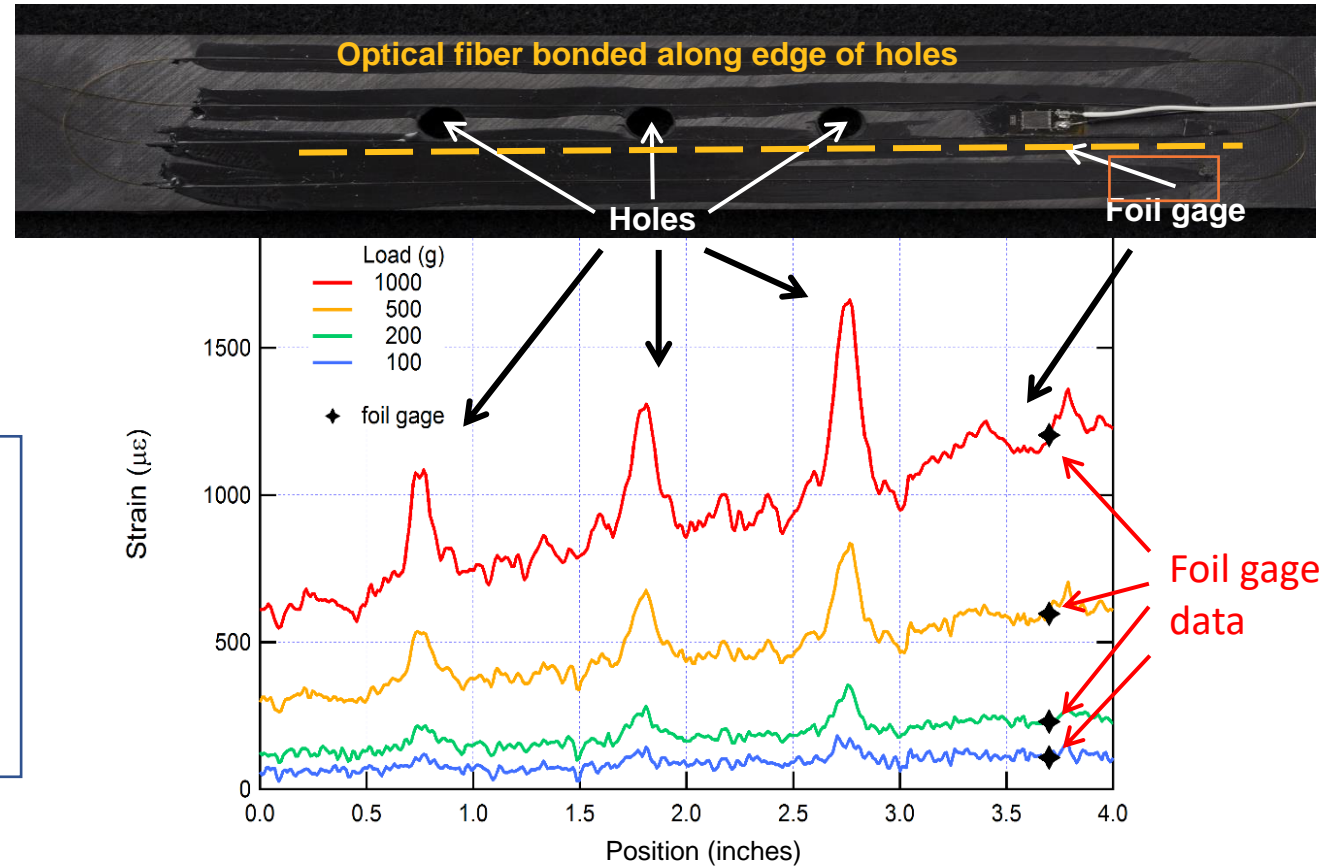
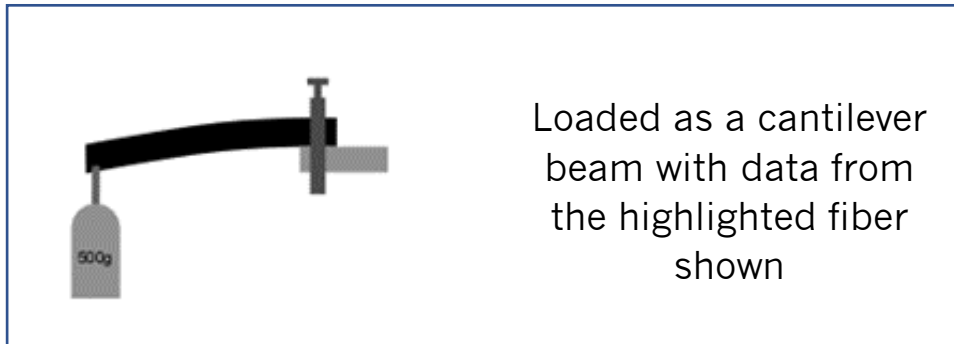


- Light, flexible fiber (155 μm)
- Static and quasi-static applications
- Strain and temperature

Distributed Sensors Complement Discrete Sensors

Consider a composite coupon with three holes drilled in the center

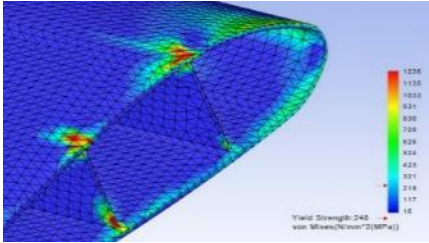
- Fiber optic sensors are installed onto the coupon along the edge of the holes
- A standard foil gage is installed onto the coupon on one end



High-Definition Fiber Optic Sensing (HD-FOS) allows users to capture data and events that might be missed if only a few gages were available or not placed near event locations

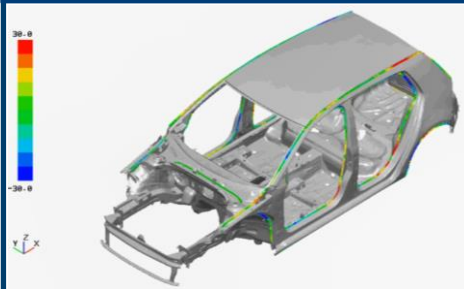
HD-FOS Addresses Key Challenges in Test and Evaluation

FEA Model Verification



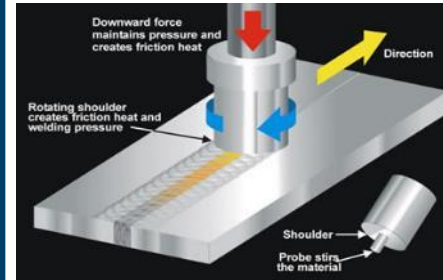
- Calibrate/verify model
- Measure complex geometries
- Comprehensive structural test data
- More complete strain data

Structural Testing



- Measure structural integrity
- Test to failure including failure mechanism
- Life cycle testing
- Fatigue testing

Material Joining & Welding



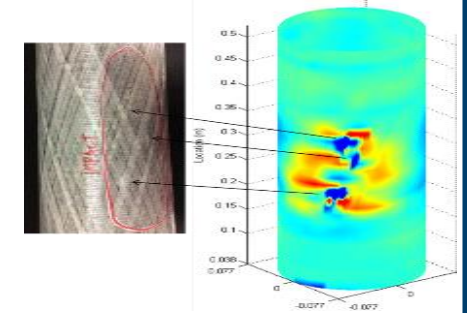
- Verify adhesive performance
- CTE mismatch effects
- Weld quality
- Weld temperature
- Post process residual strain

Manufacturing Processes



- Real-time thermal or strain mapping
- Curing temperature
- Weld temperature

Smart Parts (SHM)



- Embedded sensing for life cycle mgt.
- Composite damage detection
- Crack propagation
- Structural integrity monitoring

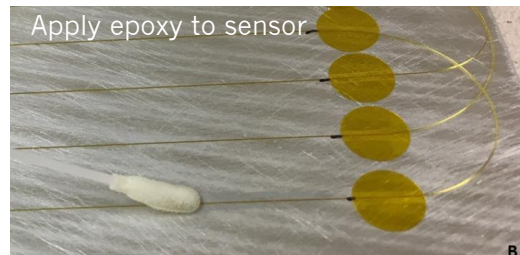
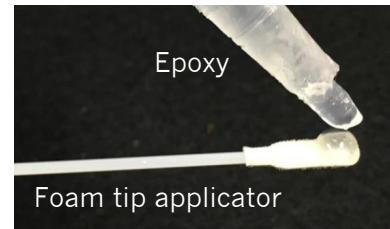
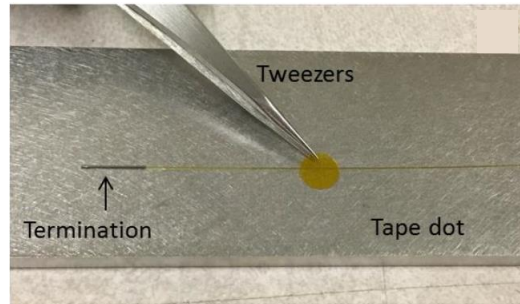
ODiSI Demonstration

A decorative graphic in the bottom right corner of the slide, consisting of several parallel white lines that curve upwards and to the right. Small white dots are placed at regular intervals along these lines, creating a sense of motion or data flow.

Sensors

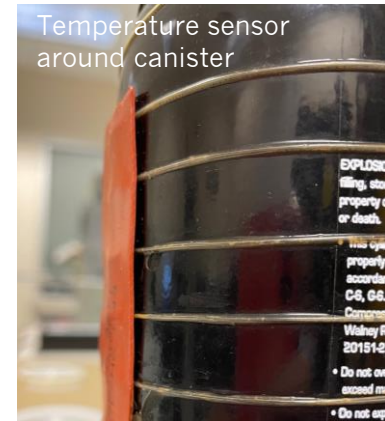
Strain Sensor

- **Prepare:** Abrade and clean the surface for bonding
- **Plan:** Identify the sensor path
- **Apply:** Lay out the sensor in its intended path
- **Bond:** Epoxy the sensor in place



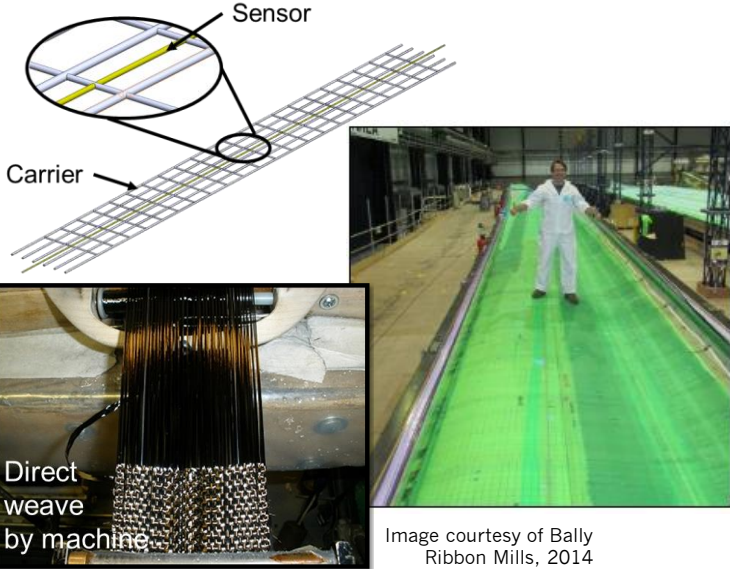
Temperature Sensor

- **Prepare:** Clean the surface
- **Plan:** Identify the sensor path
- **Apply:** Lay out the sensor in its intended path
- **Affix:** Hold down sensor to surface using tape, adhesive, or brackets



Complex Instrumented Articles

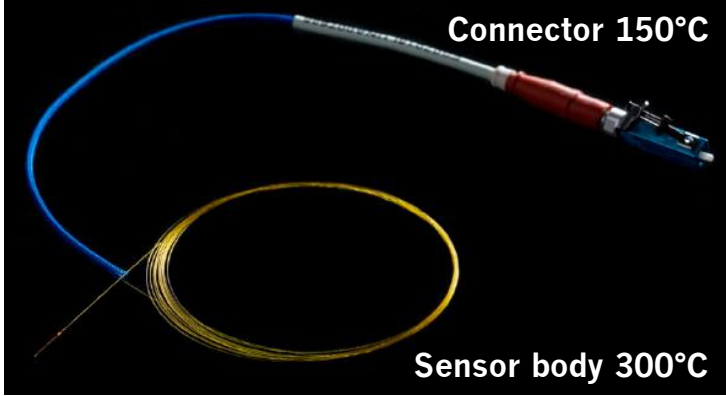
Sensor Layout and Placement



Ingress / Egress Protection

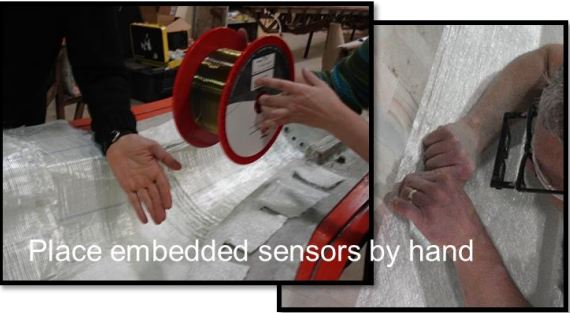
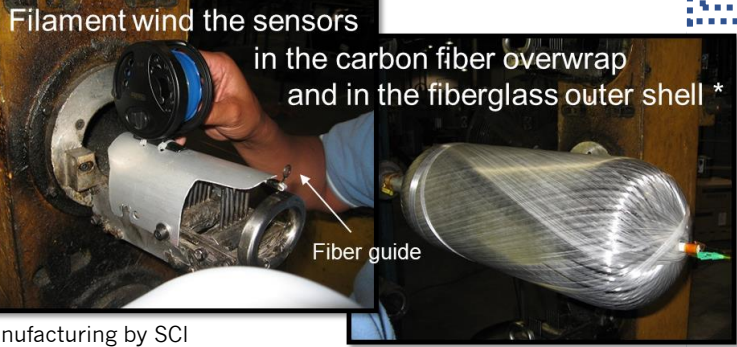
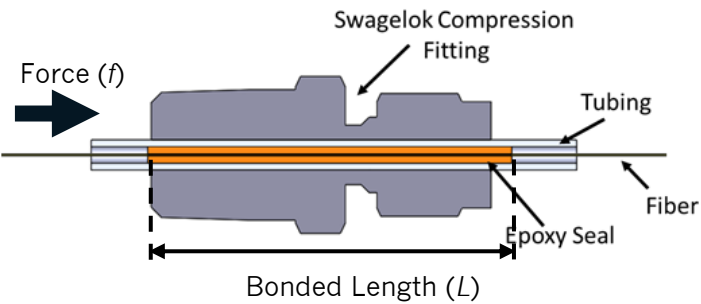


Processing Parameters – Temperature & Pressure



Oven feedthrough: silicone rubber stopper, glass wool

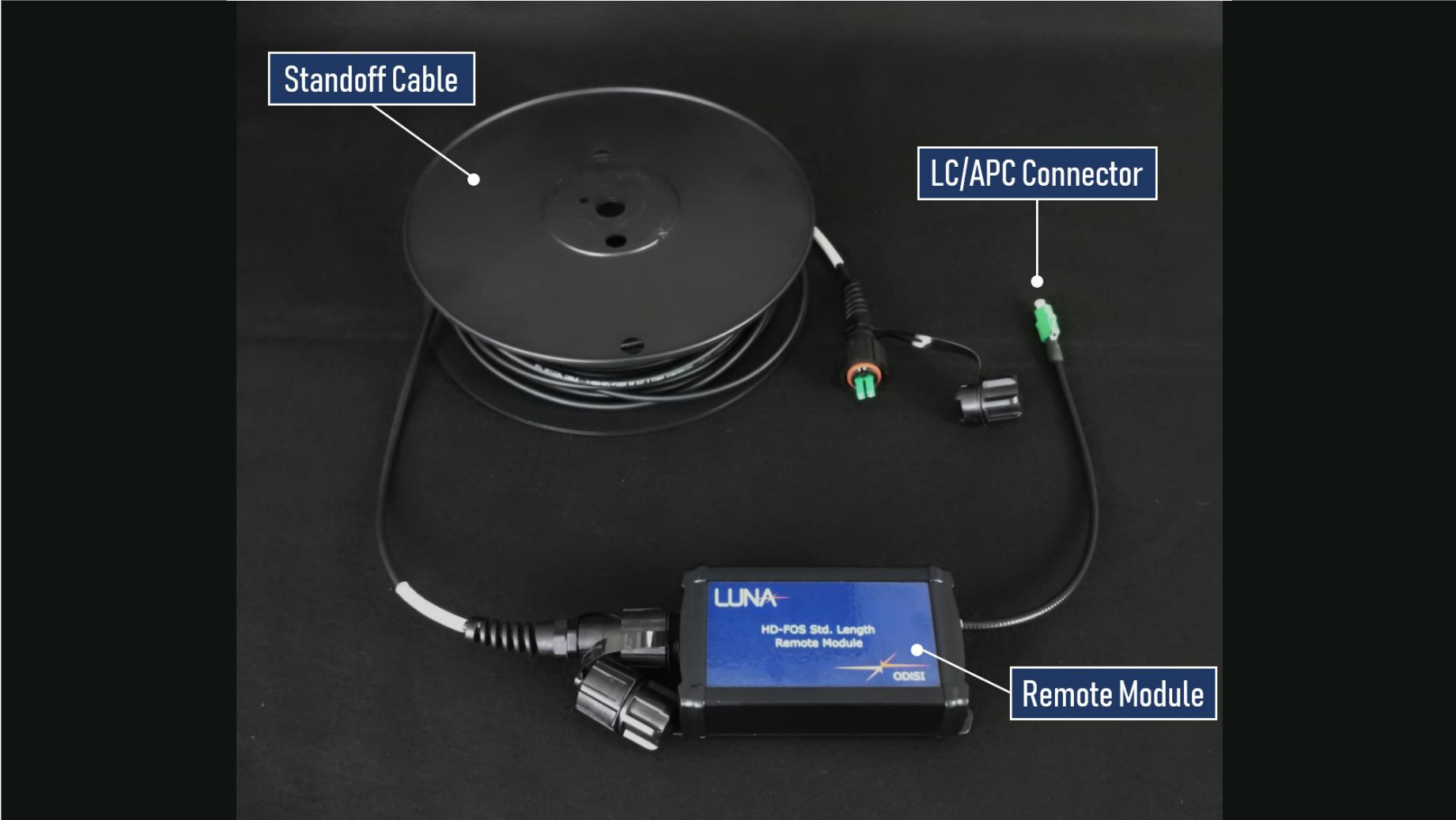
Pressure feedthrough



System Components



System Components

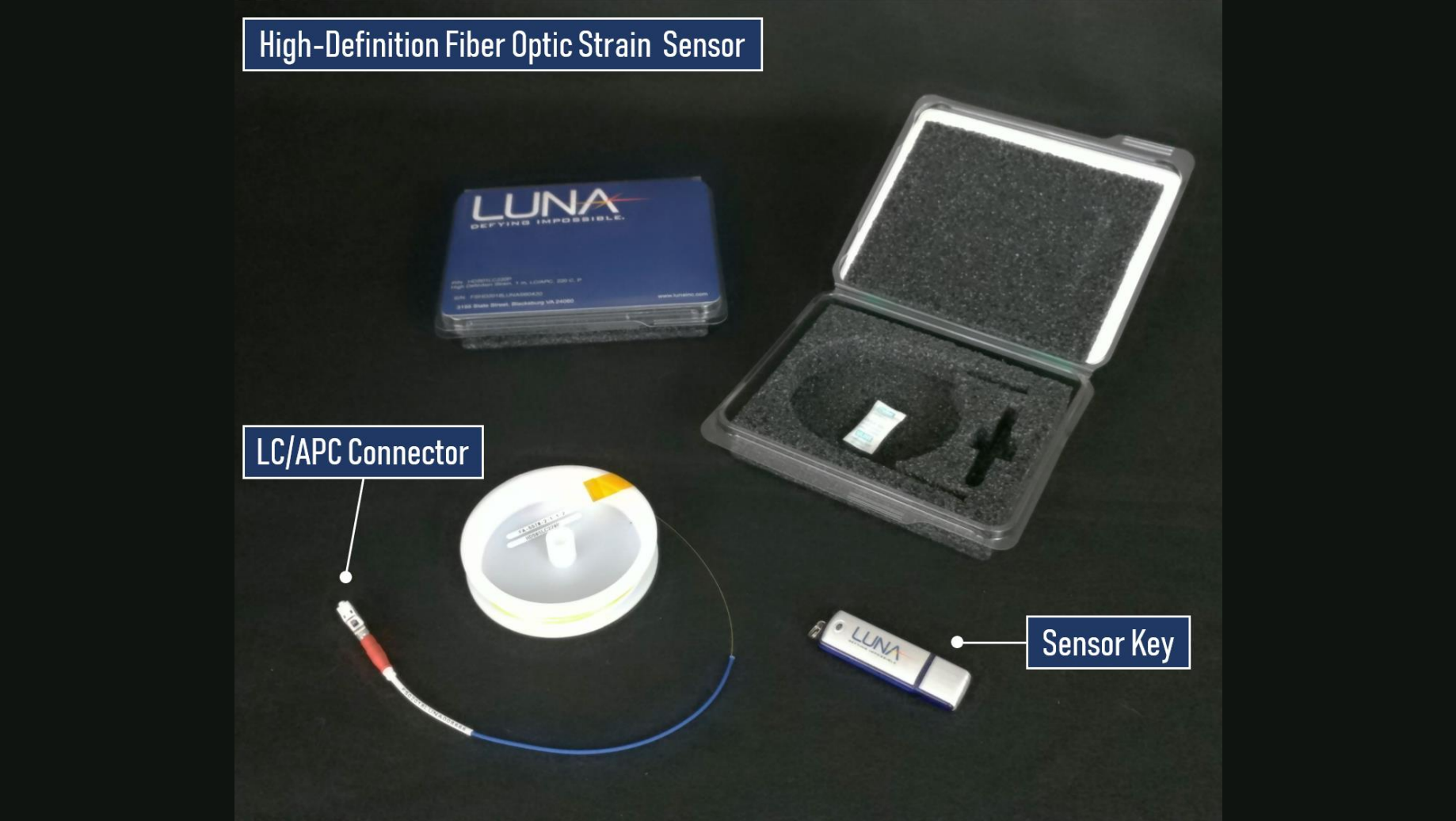


System Components

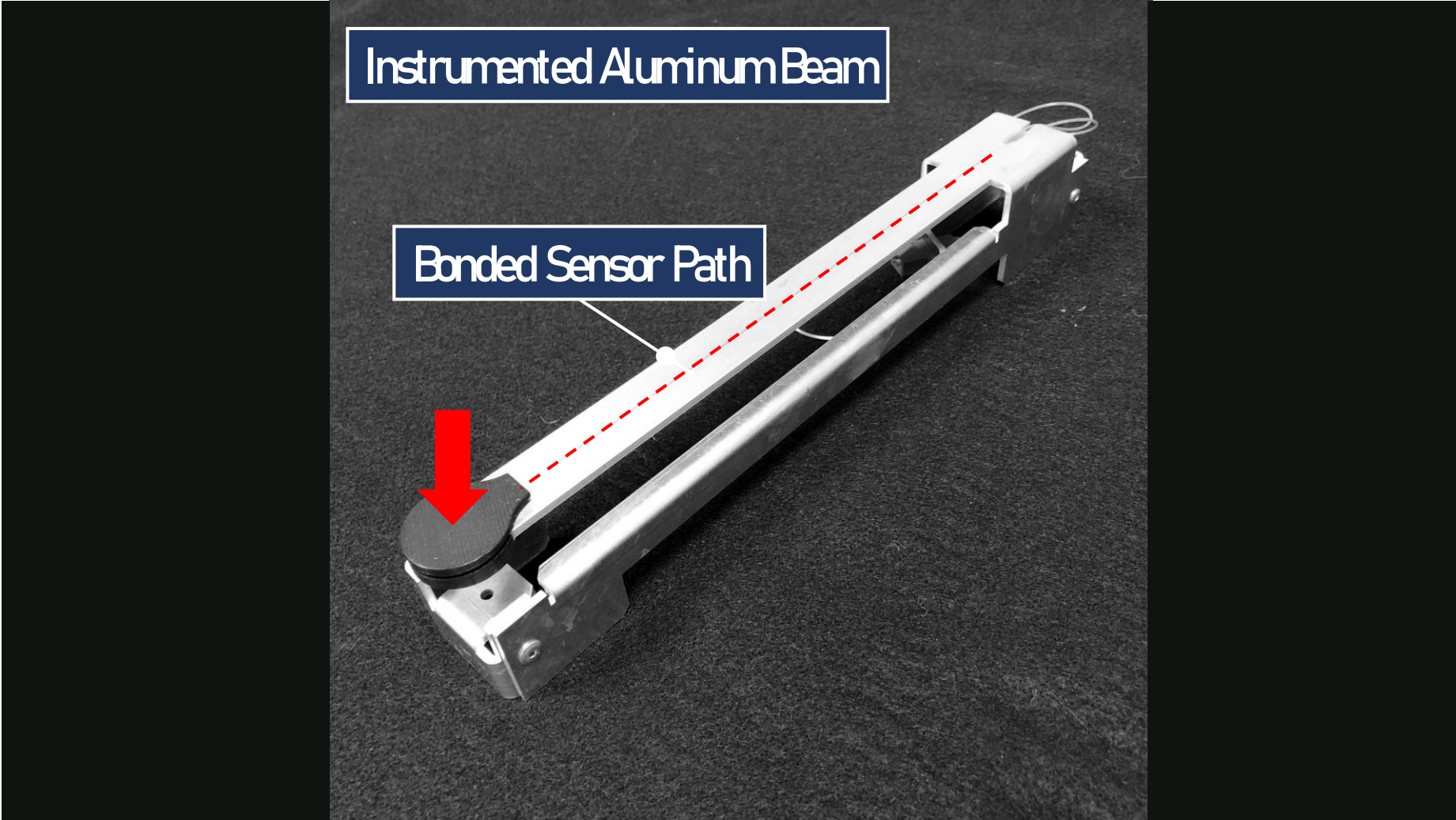
Controller



System Components



System Components



System Components

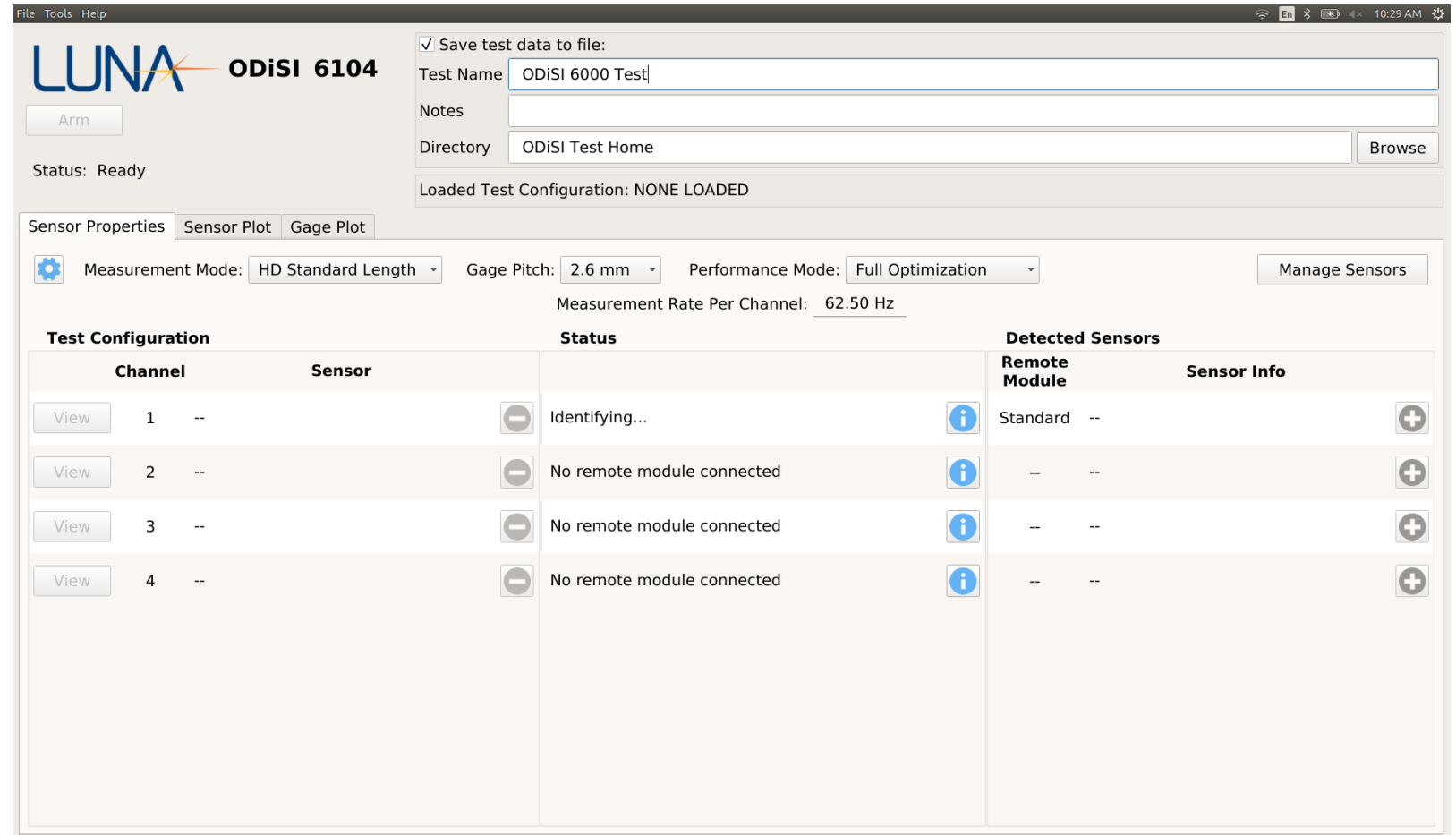


System Components



ODiSI Software – Main Interface

- Launch the software by double-clicking the “OD6” icon on the desktop
- It will take a few seconds to complete initialization
- Once the initialization is complete, the user will be able to change settings, view sensors, or collect data



ODiSI Software – Manage Files

The screenshot shows the ODiSI 6104 software interface. A 'File' menu is open, listing options such as 'Export Files to External Drive', 'Import Files from External Drive', 'Load Configuration...', 'Save Configuration...', 'Default Configuration...', and 'Delete Configuration'. The main window displays the following configuration:

- Save test data to file:** (checked)
- Test Name:** ODiSI 6000 Test
- Notes:** (empty text field)
- Directory:** ODiSI Test Home (with a 'Browse' button)
- Loaded Test Configuration:** NONE LOADED

Below the configuration, there are tabs for 'Sensor Properties', 'Sensor Plot', and 'Gage Plot'. The 'Sensor Properties' tab is active, showing:

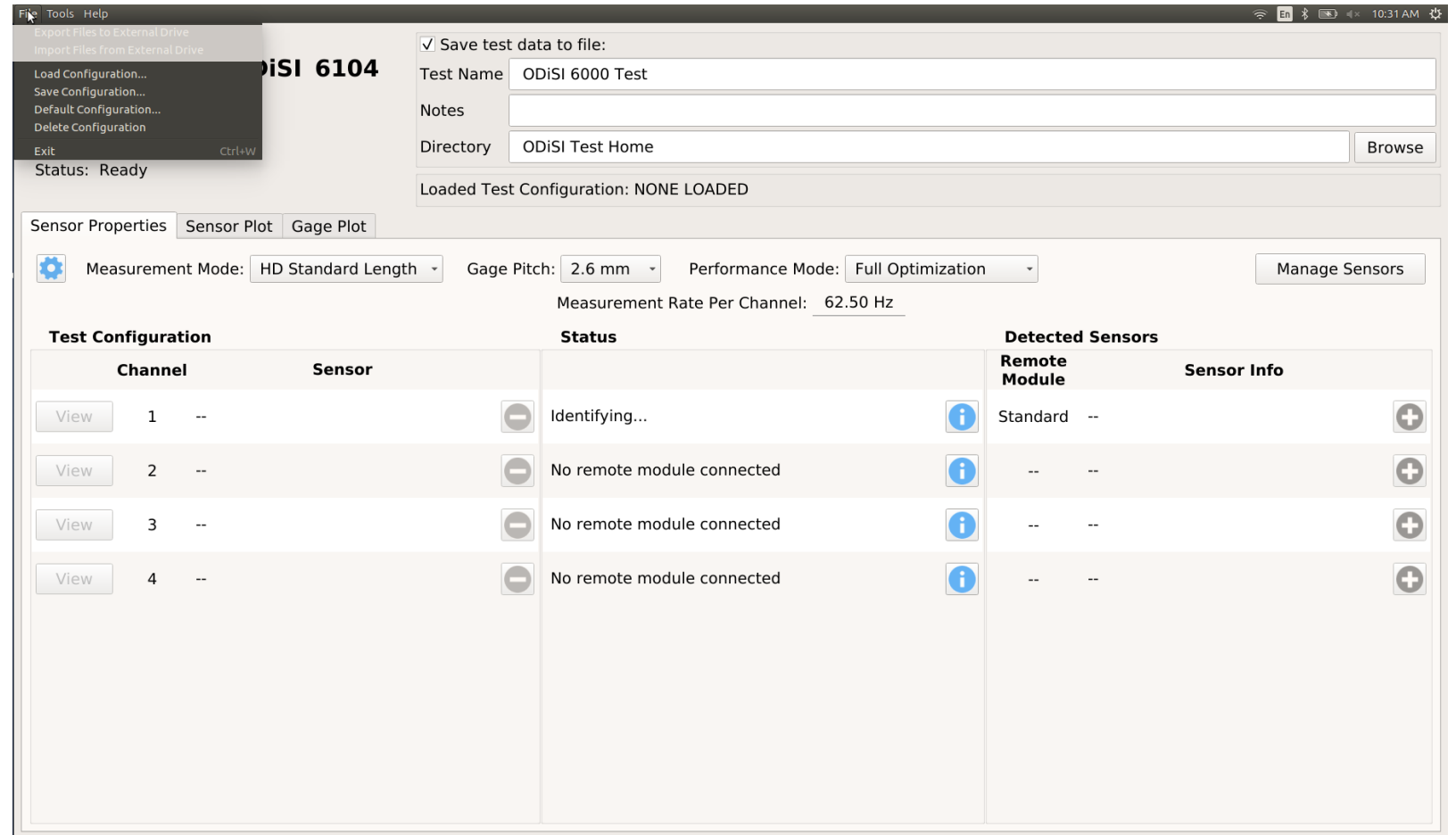
- Measurement Mode:** HD Standard Length
- Gage Pitch:** 2.6 mm
- Performance Mode:** Full Optimization
- Measurement Rate Per Channel:** 62.50 Hz
- Manage Sensors** button

The main area contains a table with the following structure:

Test Configuration			Status	Detected Sensors	
Channel	Sensor			Remote Module	Sensor Info
View	1	--	Identifying...	Standard	--
View	2	--	No remote module connected	--	--
View	3	--	No remote module connected	--	--
View	4	--	No remote module connected	--	--

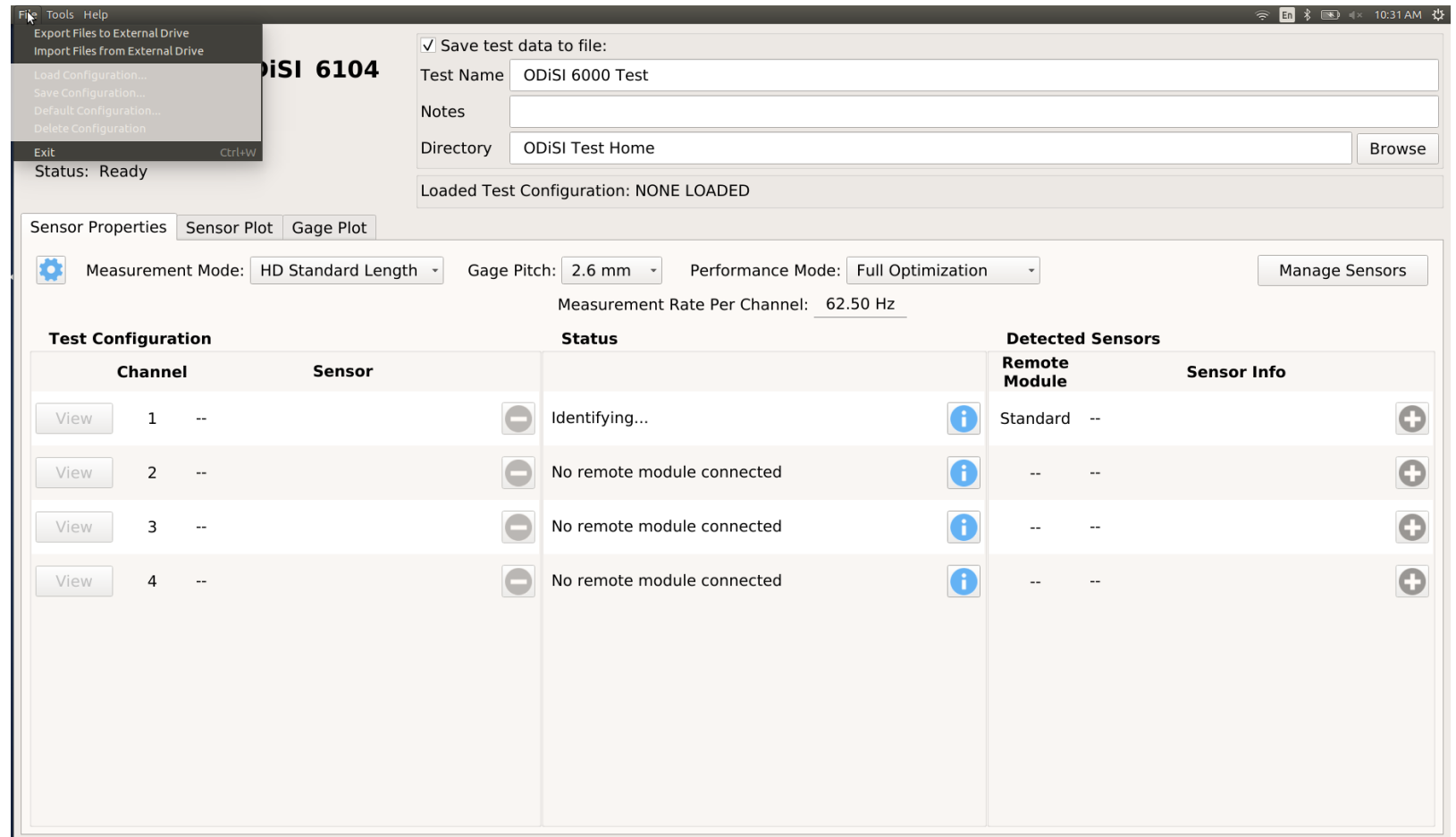
ODiSI Software – Configurations

- Save and load configurations
- Configurations remember user preferences such as operating mode or trigger options



ODiSI Software – Moving Files

- Export to, or import from, an external drive (USB or CD)



ODiSI Software – Interact with Test Data

The screenshot displays the ODiSI 6104 software interface. At the top, a menu is open with options: Generate Test Data TSV Files, Play Back Test Data, Update Feature Keys, and Time Synchronization Settings. Below the menu, there is an 'Arm' button and a 'Status: Ready' indicator. On the right, a configuration panel includes a checked 'Save test data to file:' option, a 'Test Name' field containing 'ODiSI 6000 Test', a 'Notes' field, and a 'Directory' field containing 'ODiSI Test Home' with a 'Browse' button. Below this, it states 'Loaded Test Configuration: NONE LOADED'.

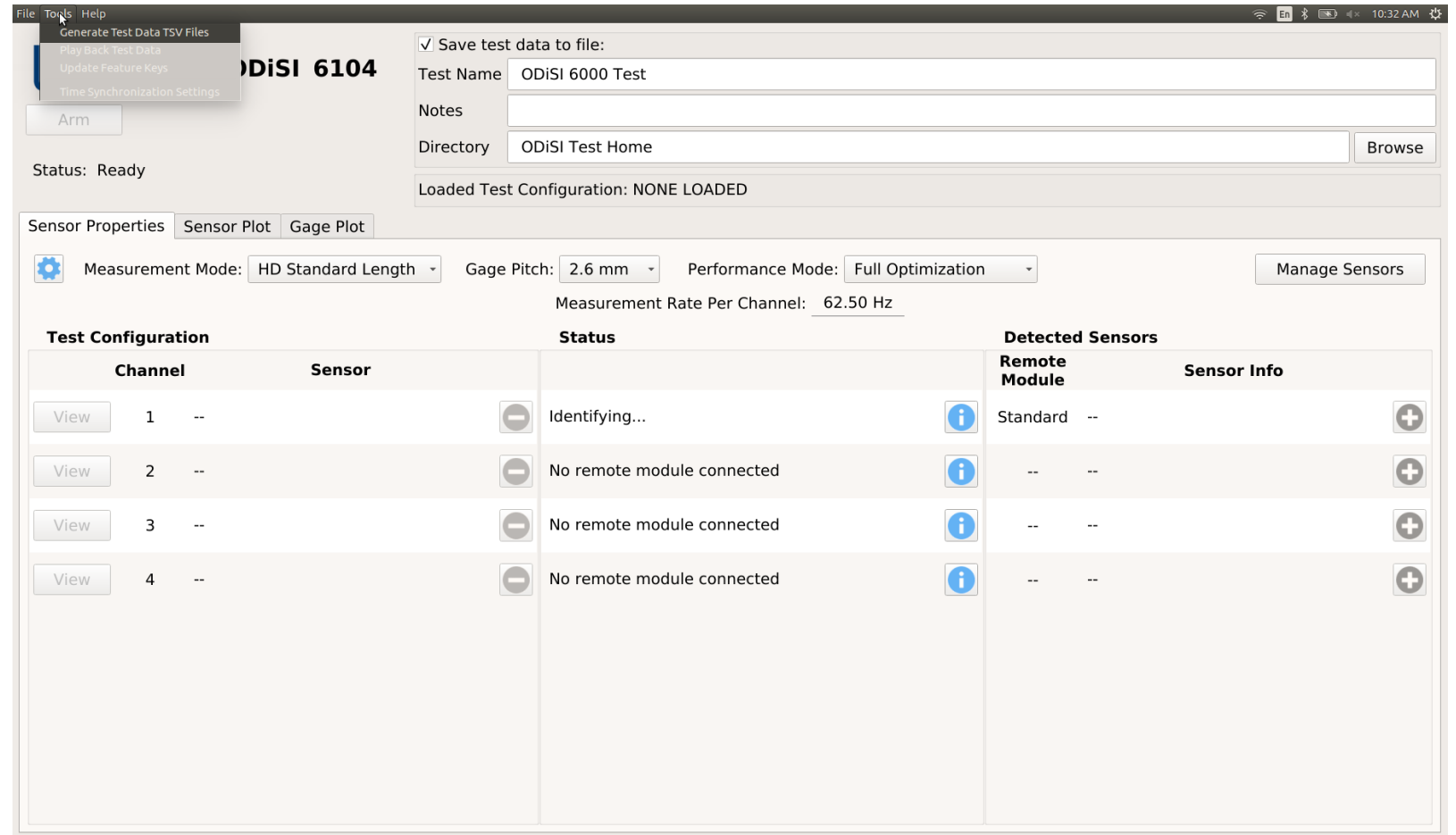
The main area features three tabs: 'Sensor Properties', 'Sensor Plot', and 'Gage Plot'. Under 'Sensor Properties', there are settings for 'Measurement Mode' (HD Standard Length), 'Gage Pitch' (2.6 mm), and 'Performance Mode' (Full Optimization), along with a 'Manage Sensors' button. A 'Measurement Rate Per Channel' is set to 62.50 Hz.

The interface contains two tables:

Test Configuration			Status	Detected Sensors	
Channel	Sensor			Remote Module	Sensor Info
View	1	--	Identifying...	Standard	--
View	2	--	No remote module connected	--	--
View	3	--	No remote module connected	--	--
View	4	--	No remote module connected	--	--

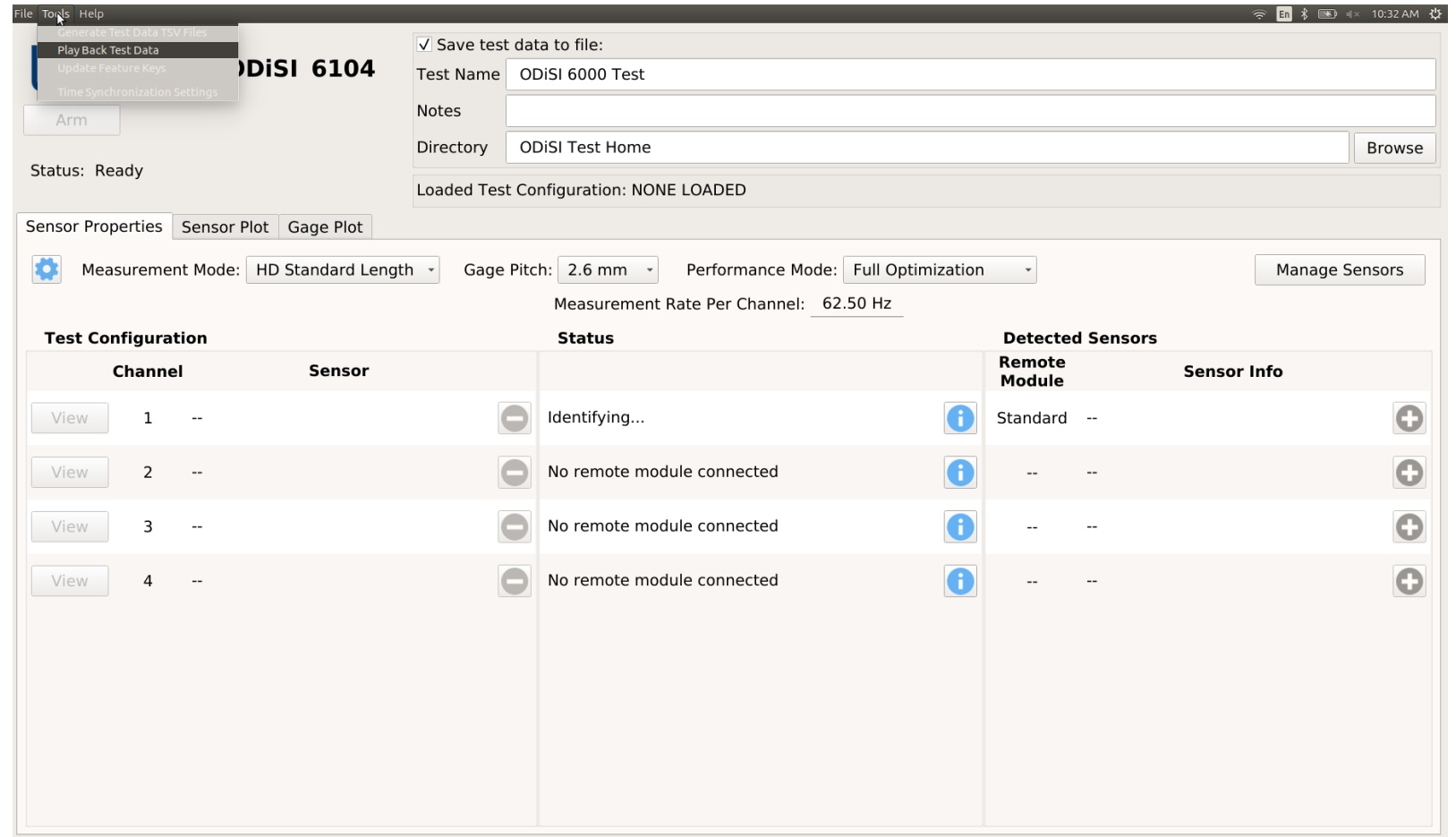
ODiSI Software – Generate Test Data TSV

- Convert measurement data from binary data files into human readable tab-delimited data files
- TSV files can be opened in Excel, Matlab, Python, LabView



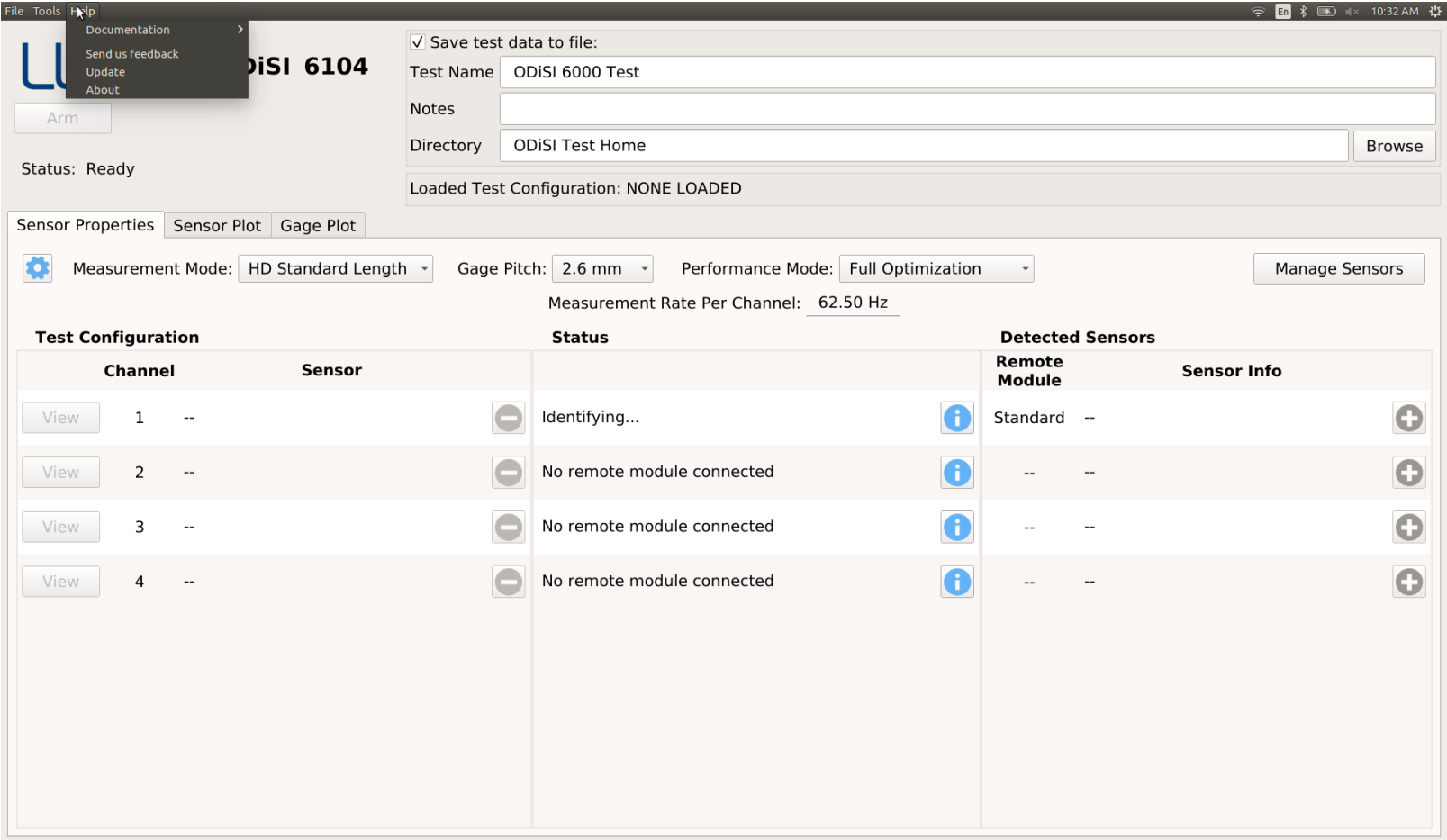
ODiSI Software – Play Back Test Data

- Run through a test that has already been completed
- Jump to any point during the data set
- Change playback speed



ODiSI Software – Help

- Look at new features
- Refer to User’s Guides
- Send feedback to Luna



ODiSI Software – Navigate Software Main Tabs

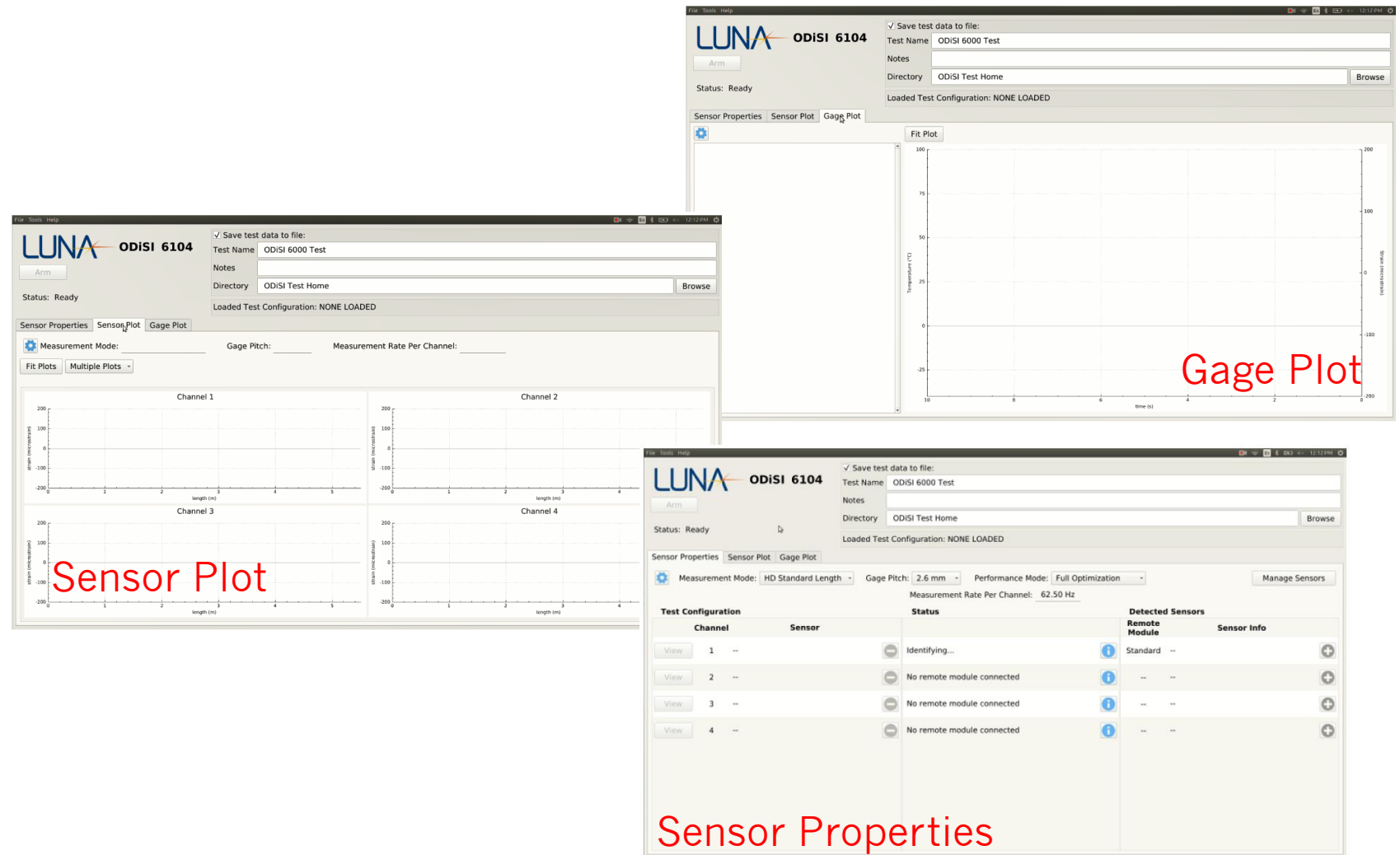
- Gage Plot: Measurement vs Time
- Sensor Plot: Measurement vs Length
- Sensor Properties: Displays status of the system, channels, sensors, access settings

The screenshot displays the ODiSI 6104 software interface. At the top, there is a menu bar with 'File', 'Tools', and 'Help'. The main header includes the 'LUNA' logo and 'ODiSI 6104'. Below this, there is an 'Arm' button and a 'Status: Ready' indicator. On the right side, there are input fields for 'Test Name' (ODiSI 6000 Test), 'Notes', and 'Directory' (ODiSI Test Home), along with a 'Browse' button. A checkbox for 'Save test data to file:' is checked. Below these fields, it says 'Loaded Test Configuration: NONE LOADED'. The main area is divided into tabs: 'Sensor Properties', 'Sensor Plot', and 'Gage Plot'. The 'Sensor Properties' tab is active, showing a gear icon, 'Measurement Mode: HD Standard Length', 'Gage Pitch: 2.6 mm', and 'Performance Mode: Full Optimization'. There is also a 'Manage Sensors' button and 'Measurement Rate Per Channel: 62.50 Hz'. Below this, there are three tables: 'Test Configuration', 'Status', and 'Detected Sensors'. The 'Test Configuration' table has columns for 'Channel' and 'Sensor'. The 'Status' table has a 'Status' column. The 'Detected Sensors' table has columns for 'Remote Module' and 'Sensor Info'. Each row in the 'Test Configuration' table has a 'View' button. The 'Status' table shows 'Identifying...' for channel 1 and 'No remote module connected' for channels 2, 3, and 4. The 'Detected Sensors' table shows 'Standard' for channel 1 and '--' for channels 2, 3, and 4.

Test Configuration		Status	Detected Sensors	
Channel	Sensor	Status	Remote Module	Sensor Info
View	1 --	Identifying...	Standard	--
View	2 --	No remote module connected	--	--
View	3 --	No remote module connected	--	--
View	4 --	No remote module connected	--	--

ODiSI Software – Navigate Software Main Tabs

- Gage Plot: Measurement vs Time
- Sensor Plot: Measurement vs Length
- Sensor Properties: Displays status of the system, channels, sensors, access settings



ODiSI Software – Settings

- Adjust Channel Settings, Streaming Properties, Trigger settings, Strain or Temperature settings, and Sampling Rate

The screenshot shows the LUNA ODiSI 6104 software interface. At the top, there is a menu bar with 'File', 'Tools', and 'Help'. Below the menu bar, the software title 'LUNA ODiSI 6104' is displayed. A 'Save test data to file:' checkbox is checked, and the 'Test Name' is 'ODiSI 6000 Test'. The 'Notes' field is empty, and the 'Directory' is 'ODiSI Test Home'. A 'Browse' button is next to the directory field. Below this, the 'Loaded Test Configuration' is 'NONE LOADED'. The 'Status' is 'Ready'. There are three tabs: 'Sensor Properties', 'Sensor Plot', and 'Gage Plot'. The 'Sensor Properties' tab is active, showing a gear icon, 'Measurement Mode: HD Standard Length', 'Gage Pitch: 2.6 mm', 'Performance Mode: Full Optimization', and 'Measurement Rate Per Channel: 62.50 Hz'. A 'Manage Sensors' button is on the right. Below the settings, there are two tables. The 'Test Configuration' table has columns for 'Channel' and 'Sensor'. The 'Detected Sensors' table has columns for 'Remote Module' and 'Sensor Info'. A red arrow points to the gear icon in the 'Sensor Properties' section.

Test Configuration		Status	Detected Sensors	
Channel	Sensor		Remote Module	Sensor Info
View	1 --	Identifying...	Standard	--
View	2 --	No remote module connected	--	--
View	3 --	No remote module connected	--	--
View	4 --	No remote module connected	--	--

ODiSI Software – Select Operational Mode

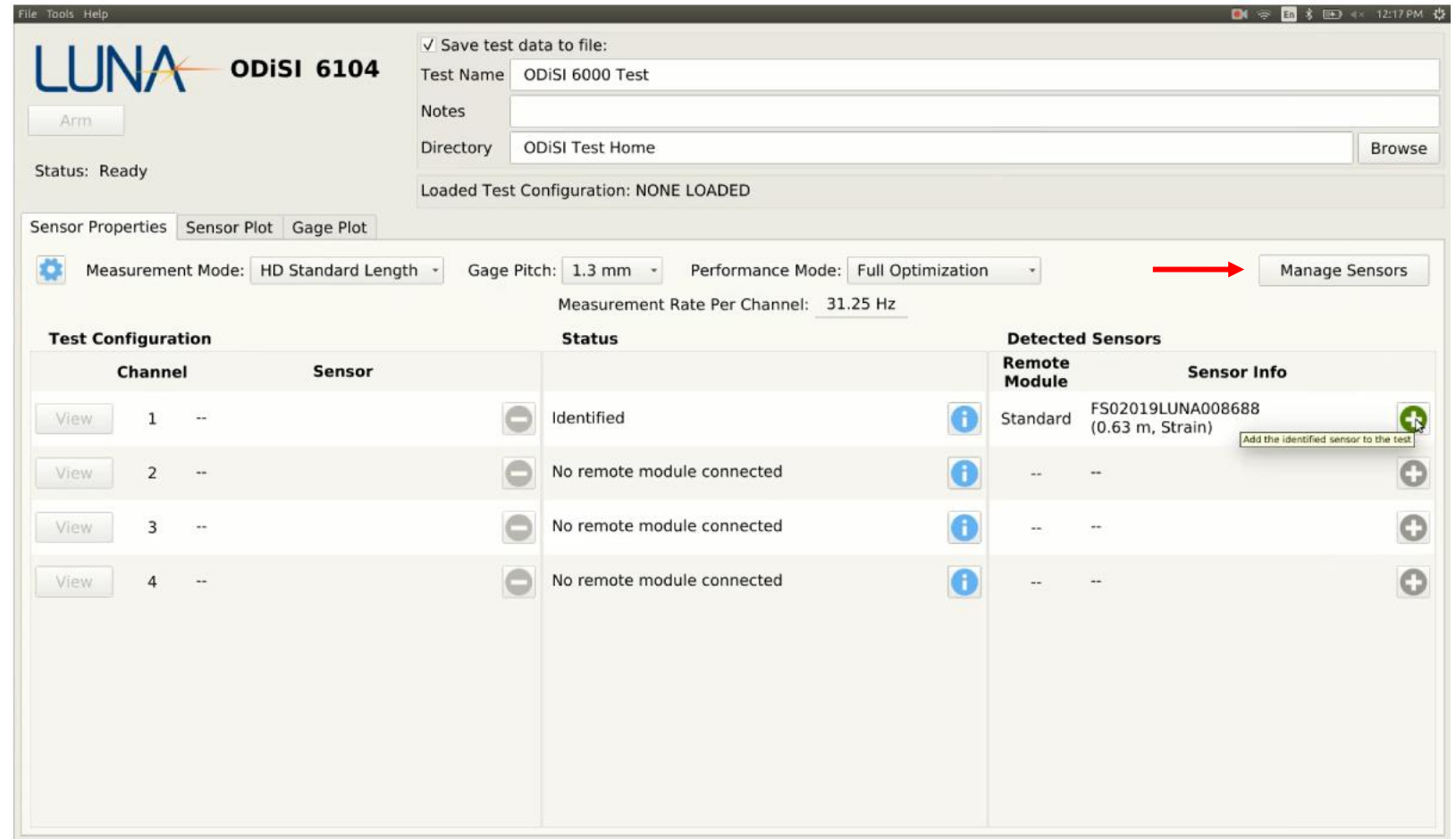
- Measurement Mode: Standard (up to 20 m sensor) or Extended (up to 50 m sensor)
- Gage Pitch: select 0.65mm for high strain gradients
- Performance Mode:
 - Full Optimization for highest quality data
 - Maximum Rate for fastest rate

The screenshot shows the LUNA ODiSI 6104 software interface. The top bar includes 'File Tools Help' and system icons. The main window displays 'LUNA ODiSI 6104' and 'Status: Ready'. A red box highlights the 'Measurement Mode' dropdown set to 'HD Standard Length', 'Gage Pitch' dropdown set to '2.6 mm', and 'Performance Mode' dropdown set to 'Full Optimization'. Below this, the 'Measurement Rate Per Channel' is set to '62.50 Hz'. The interface includes a 'Test Configuration' table and a 'Detected Sensors' table.

Test Configuration		Status		Detected Sensors	
Channel	Sensor			Remote Module	Sensor Info
View	1 --	-	Identifying...	i	Standard -- +
View	2 --	-	No remote module connected	i	-- -- +
View	3 --	-	No remote module connected	i	-- -- +
View	4 --	-	No remote module connected	i	-- -- +

ODiSI Software – Install Sensor Key

- Each sensor has a unique key that enables the system to automatically recognize the connected fiber
- Sensor keys can be Installed, Uninstalled, Deleted, Renamed
- Once a sensor is plugged into the remote module, the system will automatically recognize the sensor



ODiSI Software – Run Test

- Tare: Zero out measurements before test start
- Arm: Prepare system for logging
- Start: Start logging data
- Select gages to display in Gage Plot



ODiSI Software – Touch-to-Locate

- Identify specific gages of interest using freeze spray or soldering iron set to low

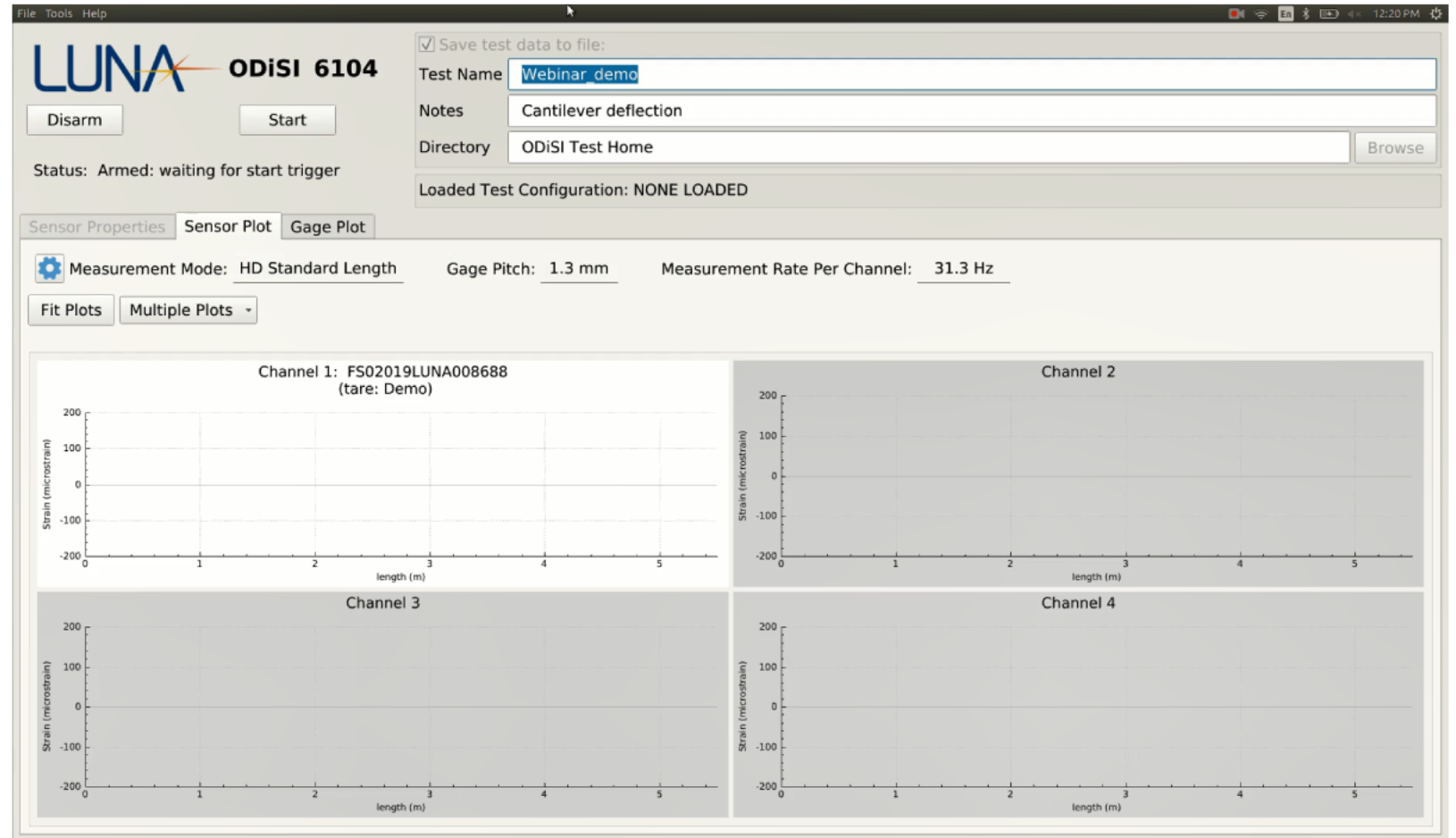
The screenshot displays the ODiSI 6104 software interface. At the top, there is a menu bar with 'File', 'Tools', and 'Help'. Below the menu is the 'LUNA ODiSI 6104' logo and an 'Arm' button. The status is 'Ready'. On the right, there are fields for 'Test Name' (ODiSI 6000 Test), 'Notes', and 'Directory' (ODiSI Test Home) with a 'Browse' button. A checkbox 'Save test data to file:' is checked. Below this is a 'Sensor Properties' section with tabs for 'Sensor Plot' and 'Gage Plot'. The 'Gage Plot' tab is active, showing a 'Channel: 1' dropdown and a 'Hide Gages' button. A 'Rekey' dropdown is set to '--', and there are 'Delete Key', 'Save Tare', 'tare', and 'Delete Tare' buttons. A 'New Gage' section has input fields for 'Name' and 'Location (m)' (0.2204), and 'Start' and 'Add Gage' buttons. A table lists gage locations:

Gage Name	Location (m)
1 Start	0.08000
2 End	1.27405
3	

Below the table is a video inset showing a hand using a tool on a component. At the bottom, there is a 'Fit Plot' button and a 'Gage Pitch: 2.6 mm' label. A plot shows 'Strain (microstrain)' on the y-axis (ranging from -400 to 200) and distance on the x-axis (ranging from 0 to 1.25). The plot title is 'Channel 1: FS2020CUSTOM_200360159_1588607050'. A sharp peak is visible at approximately 0.22 m.

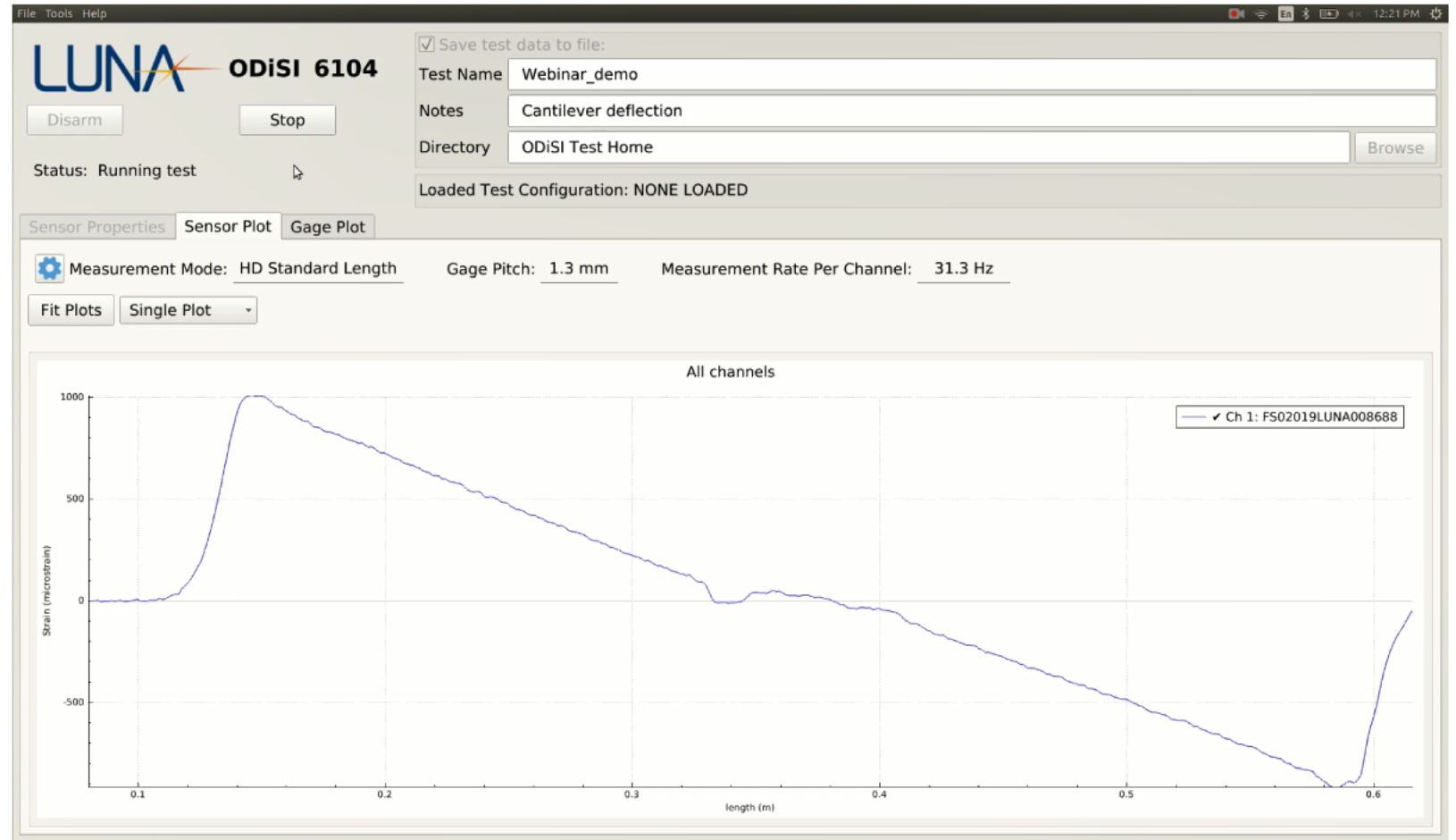
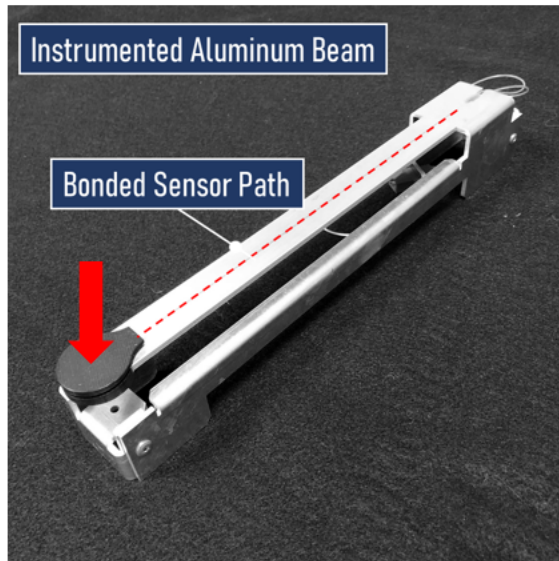
ODiSI Software – Start Test

- Display Strain vs Length



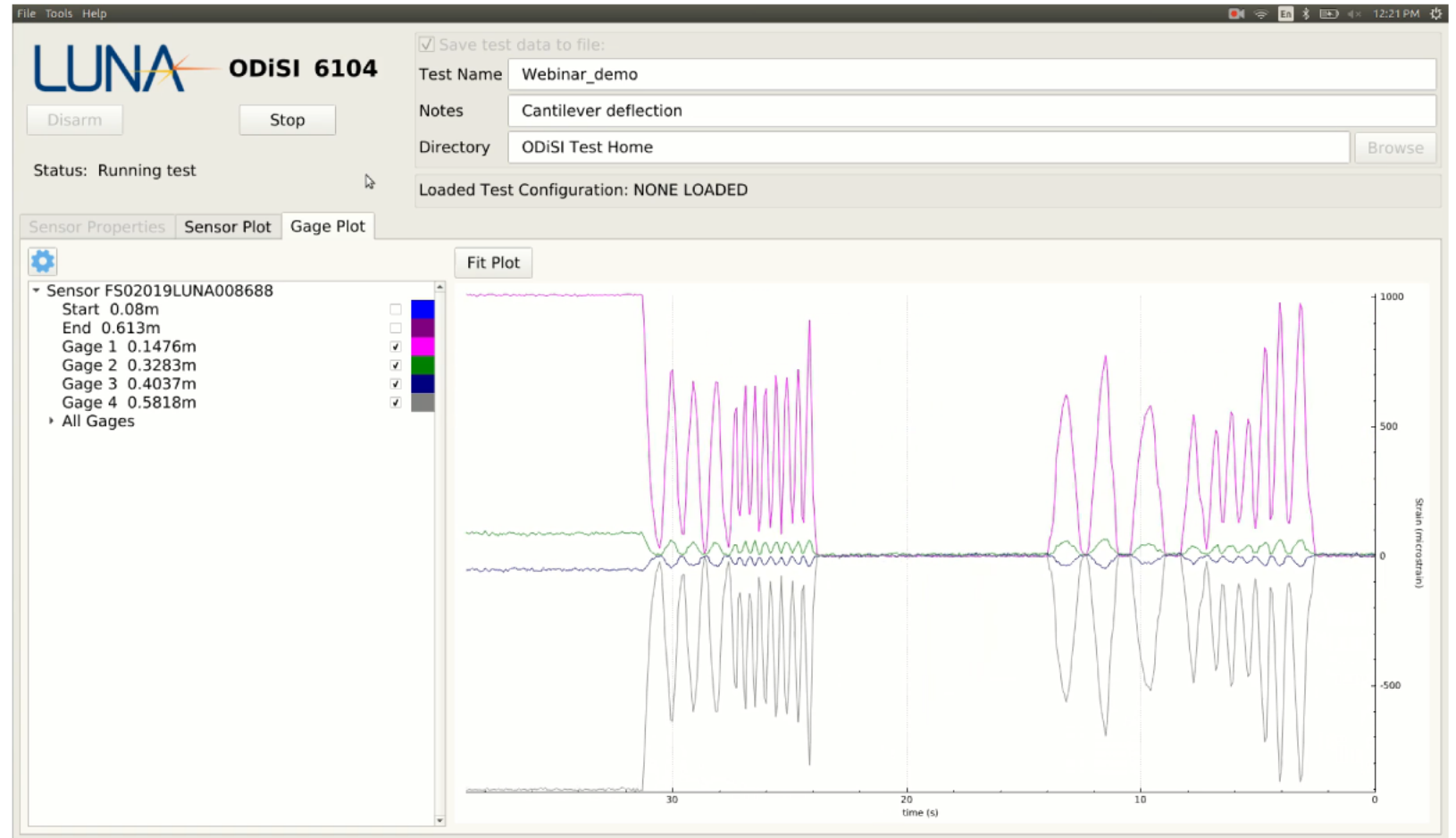
ODiSI Software – Sensor Plot

- Display Strain vs Length
- Monitor entire sensor throughout test



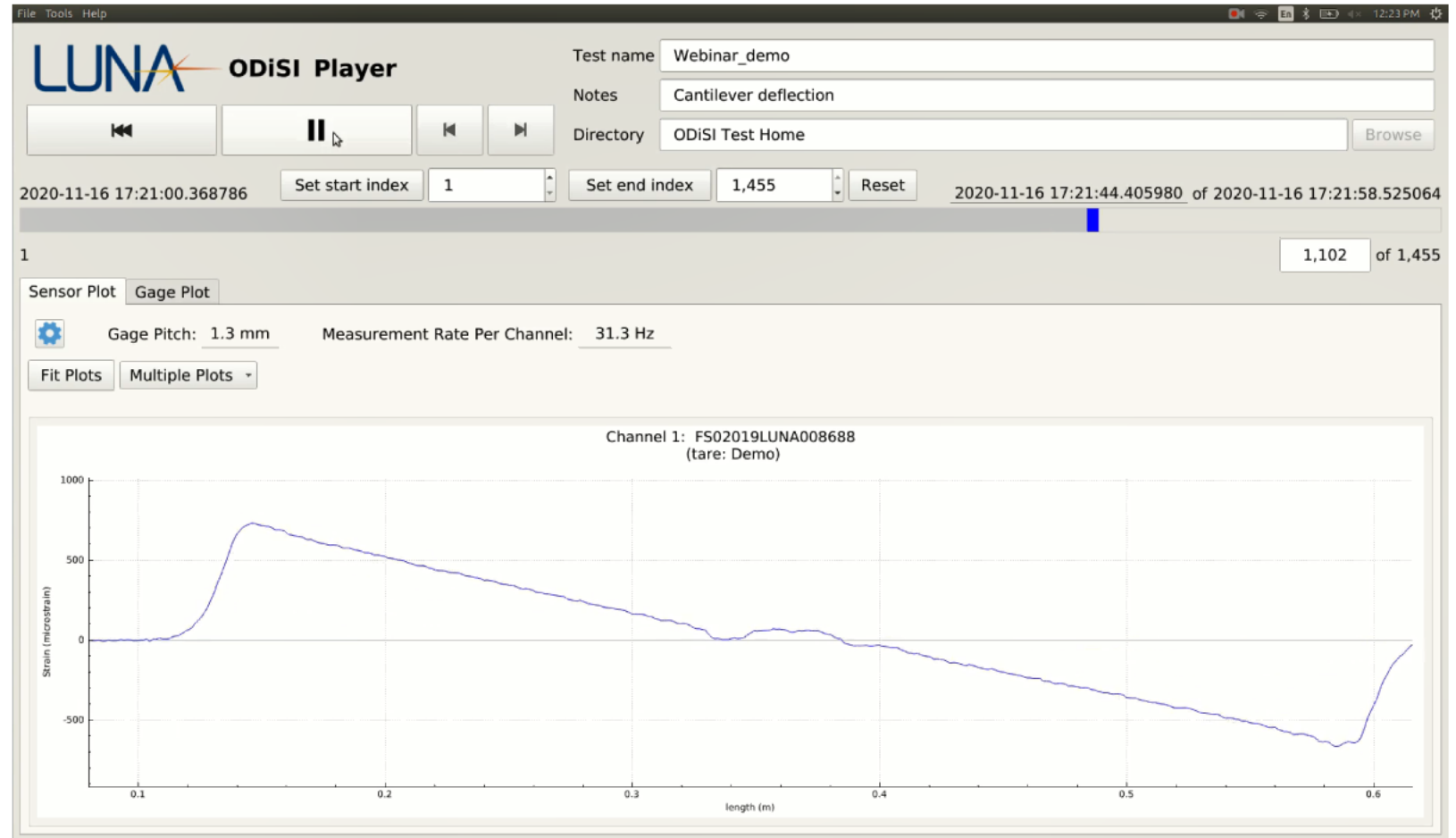
ODiSI Software – Gage Plot

- Display Strain vs Time
- Monitor individual gages over time



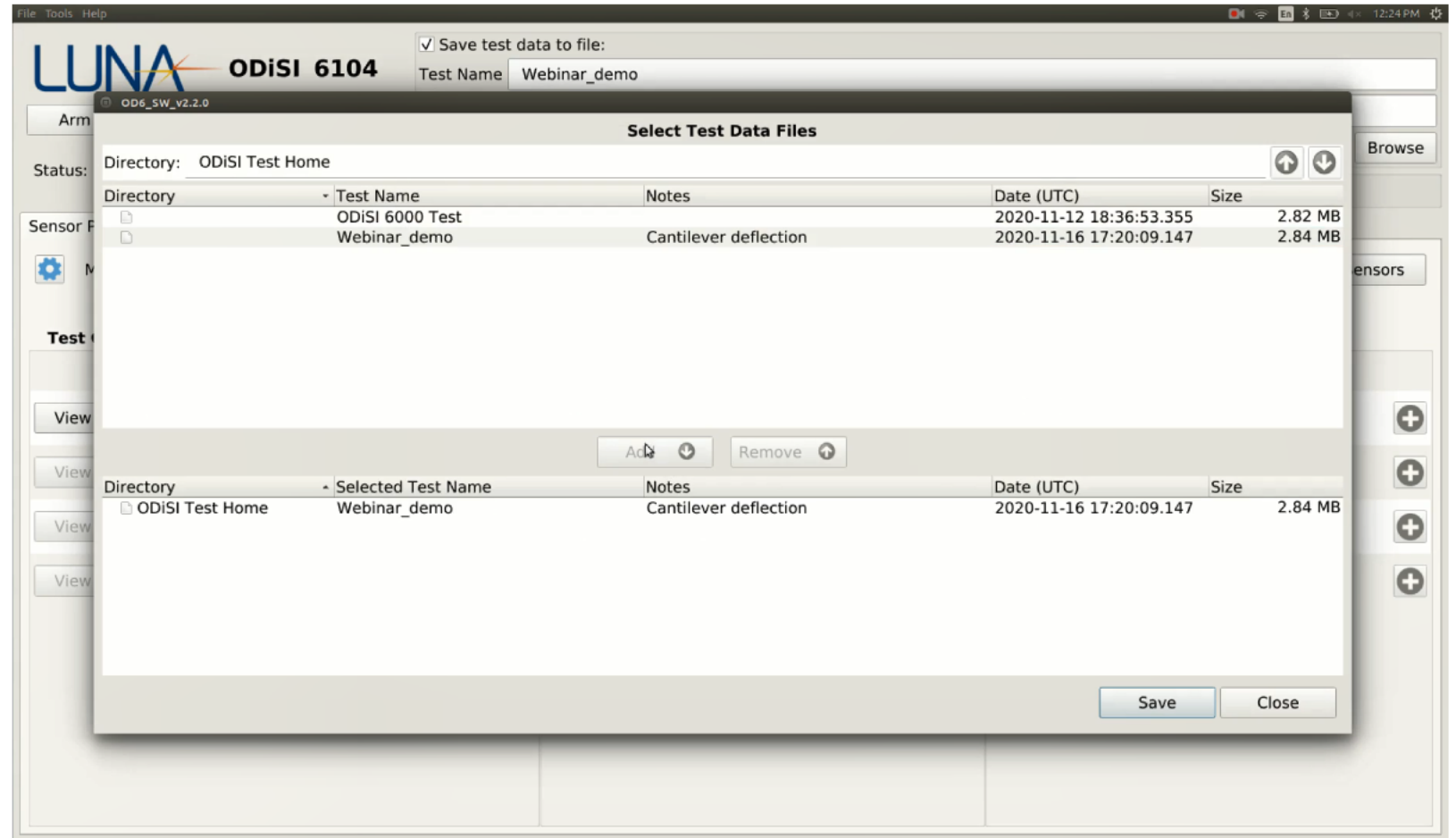
ODiSI Software – Play Back Logged Data

- Run through a test that has already been completed
- Jump to any point during the data set
- Change playback speed



ODiSI Software – Convert to TSV

- Convert measurement data from binary data files into human readable tab-delimited data files
- TSV files can be opened in Excel, Matlab, Python, LabView



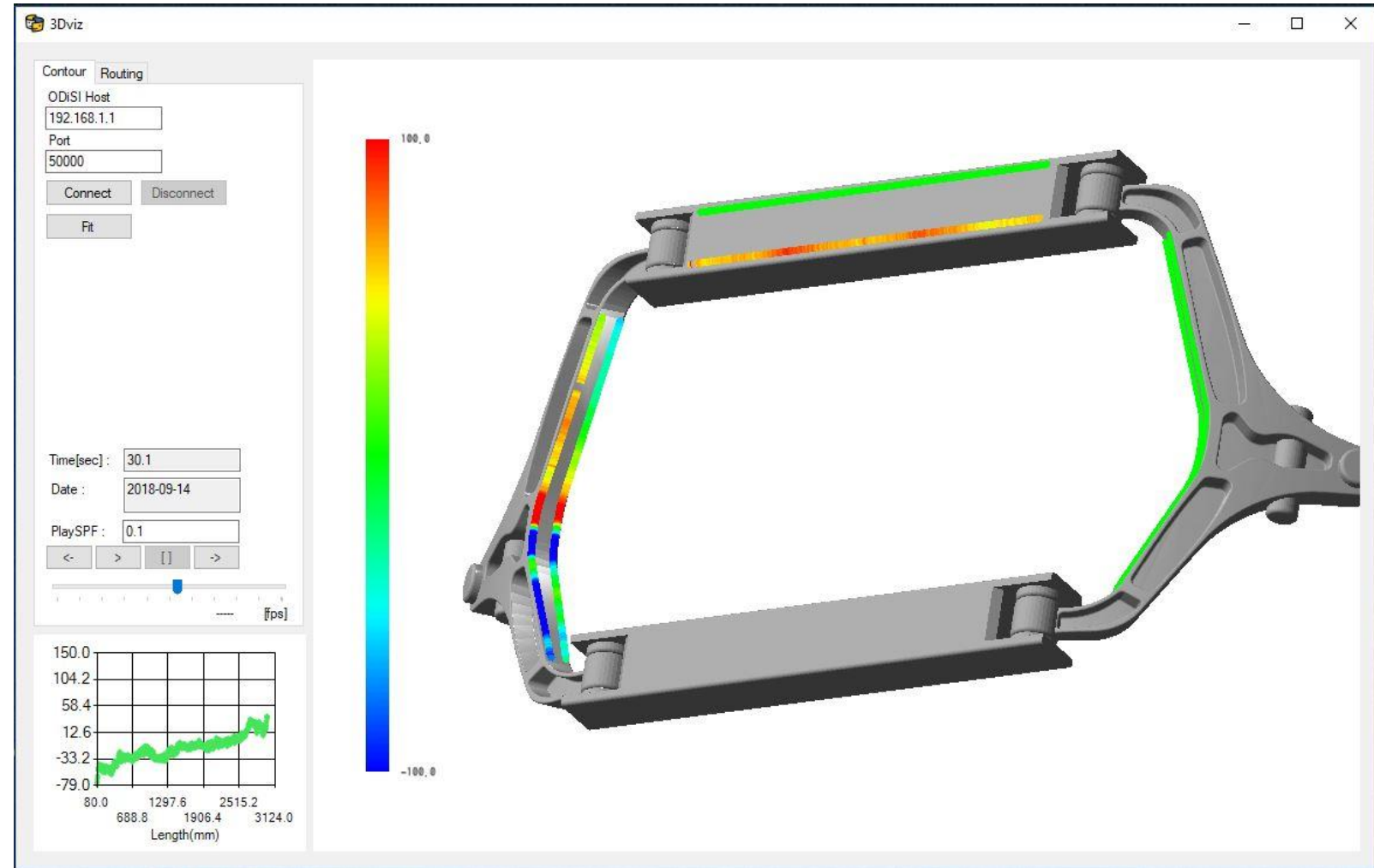
ODiSI Data Analysis

- Strain or temperature data is recorded in a 2-dimensional matrix where each row is a separate scan in time and each column is a location along the sensor
- Tab delimited data files can be read into Excel, Matlab, Python, LabView, etc.

	A	B	C	D	E	F	G	H	I	J	K	
1	Test name:	Webinar_demo										
2	Notes:	Cantilever deflection										
3	Product:	ODiSI 6104										
4	Date:	2020-11-16 17:20:09.147000										
5	Timezone:	UTC+0										
6	File Type:	ODiSI 6xxx Data File										
7	File Version:		8									
8	System Serial Number:	SIERRA										
9	Software Version:	2.2.0										
10	Hardware Version:		1									
11	Firmware Version:	1.6.7 (09/11/2020)										
12	FPGA Version:	v7.3.2-01016-rc1 (09/11/2020)										
13	Measurement Rate Per Channel:	31.25 Hz										
14	Gage Pitch (mm):		1.3									
15	Standoff Cable Length (m):		50									
16	Temperature offset:		0									
17	Performance Mode:	Full Optimization										
18	Spatial Average Window Size (gages):		0									
19	Temporal Average Window Size (gages):		0									
20	Channel:		1									
21	Sensor Name:	FS02019LUNA008688										
22	Sensor Serial Number:	FS02019LUNA008688										
23	Sensor Part Number:	HDS01LC220P										
24	Sensor Type:	Strain										
25	Units:	microstrain										
26	x-axis units:	m										
27	Length (m):		0.628731									
28	Patch cord length (m):		0									
29	Key name:											
30	Tare name:	Demo										
31												
32	Gage/segment name			Start	End	Gage 1	Gage 2	Gage 3	Gage 4	All Gages[0]	All Gages[1]	All G
33	Tare	strain		0.3	-17.6	32.5	-10.8	-32.2	-52.2	0.3	0.7	
34	x-axis			0.08	0.613	0.1476	0.3283	0.4037	0.5818	0.08	0.0813	
35	2020-11-16 17:21:00.368786	measurement	strain	6	4.4	-0.3	2.8	-1.4	8.1	6	11	
36	2020-11-16 17:21:00.408796	measurement	strain	7.7	-0.6	1.5	8.3	-3.3	-1.5	7.7	12	
37	2020-11-16 17:21:00.448781	measurement	strain	9.3	1.9	1.2	1.3	4.5	9.1	9.3	7.1	
38	2020-11-16 17:21:00.488791	measurement	strain	4	5.9	-1	2.7	4.7	8.2	4	1.4	
39	2020-11-16 17:21:00.528776	measurement	strain	11.5	3.5	0	-4.1	-3.2	0.2	11.5	4.8	
40	2020-11-16 17:21:00.568786	measurement	strain	10.6	3.3	4.4	7.5	-1.7	2.5			
41	2020-11-16 17:21:00.608771	measurement	strain	2.5	2.7	0.8	7.1	5.3	-2.6			
42	2020-11-16 17:21:00.648780	measurement	strain	4	-3.9	0.5	3.7	-2	1.1			

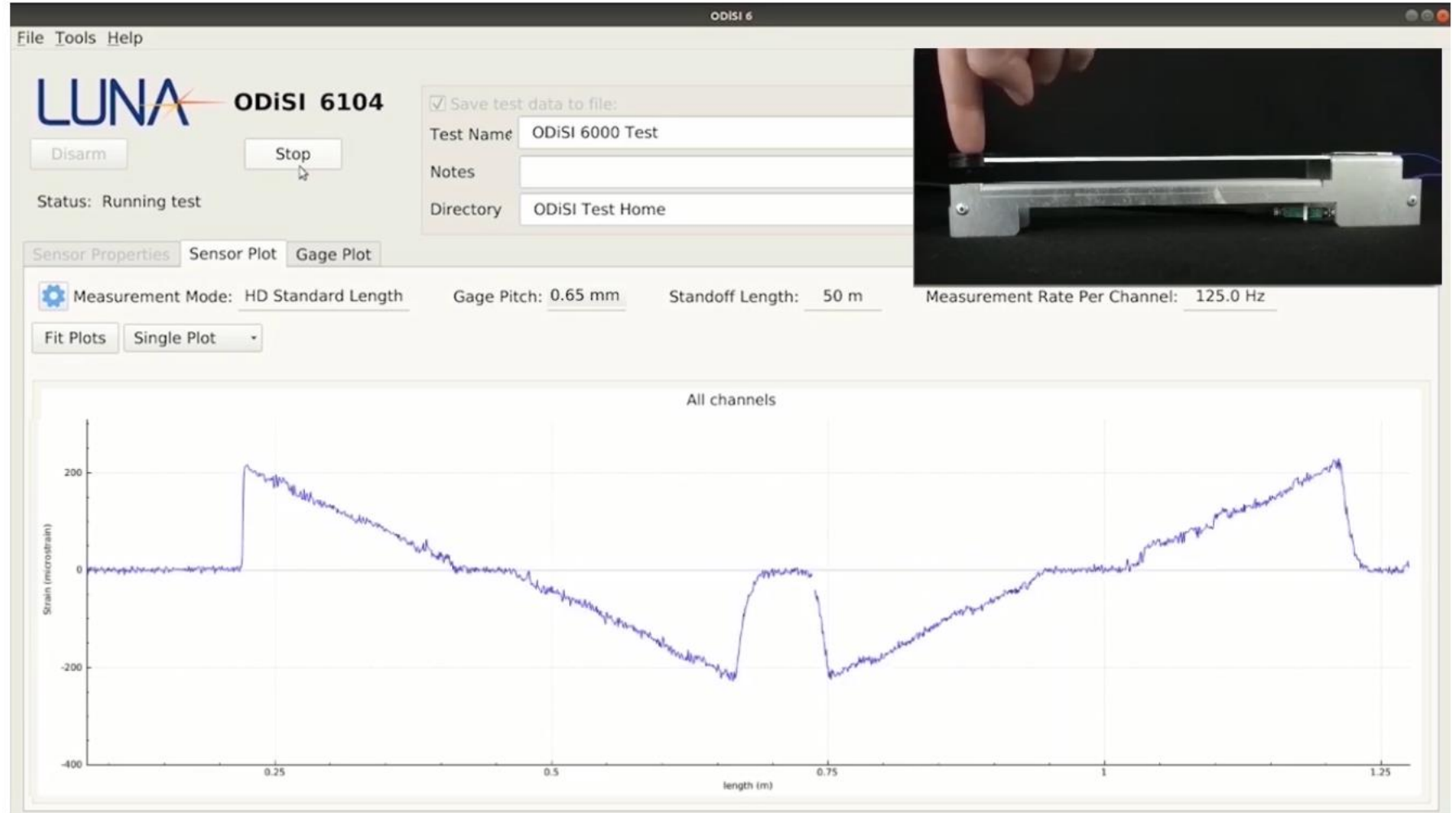
3D Data Visualization

- Display data as color map over test article image or 3D model

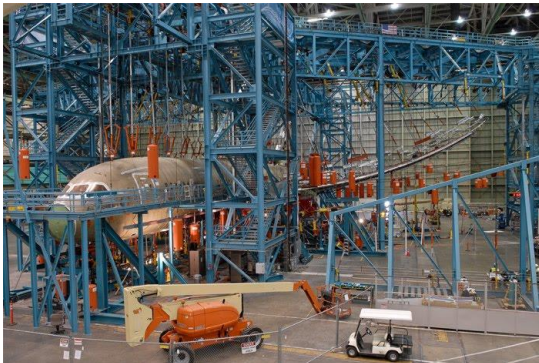


Summary: How to Use an ODiSI

- Install a keyed sensor onto a test article
- Use the ODiSI software to identify gages of interest
- Select data logging parameters
- Log data during a test and/or stream to a network location
- Play back data post-test



Fiber Sensing Advantages



Luna's high-definition fiber optic sensing solution allows materials, structures and systems to be seen like never before:

- Instrument complex geometries to validate models
- Embed fiber sensors in composite structures and monitor structural health and aging
- Provide feedback control for manufacturing processes
- Create smart parts through sensor integration
- Implement predictive maintenance through embedded sensors

Learn More

- Luna's Website:
 - <https://www.lunainc.com>
- ODiSI 6000 web page:
 - <https://lunainc.com/product/odisi-6000-series>
- ODiSI 6000 Data Sheet:
 - <https://lunainc.com/sites/default/files/assets/files/data-sheet/LUNA-ODiSI-6000-Data-Sheet.pdf>
- ODiSI 6000 User's Guide:
 - <https://lunainc.com/sites/default/files/assets/files/resource-library/ODiSI%206100%20User%20Guide.pdf>

Thank you! Questions?

Q&A

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<https://lunainc.com/events/learn-luna-explainer-webinar-series>