WIND TURBINE TOWER MONITORING

QUAKE SERIES

by QuakeLogic

Measured evidence for the tower and its foundation: natural frequencies, fatigue, tilt and earthquakes on one GPS time base.



SENSE-AI for Wind Turbines

POWERED BY AI

For wind farm owners, operators and O&M service providers.

MANUFACTURED IN USA
from U.S. and imported parts
Designed, Software Development and Manufactured in Roseville, California

CUSTOMER SATISFACTION 100% GUARANTEED

QuakeLogic Inc. · Roseville, California
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EXECUTIVE SUMMARY

The tower and the foundation are the parts of a wind turbine that are never swapped out. Blades, gearboxes and generators are replaced on a schedule; the steel shell, its bolted flanges and the foundation are expected to last the full life of the asset and, more and more often, beyond it. Yet most turbines still run on design assumptions for these components rather than on measured behaviour.

SENSE-AI for Wind Turbines is a complete structural health monitoring system for one steel tower from the QuakeLogic Quake Series. Eight MODALINK-PRO nodes measure acceleration and tilt from the nacelle to the foundation. Four digital strain gauges measure bending at the tower base. A QUAKEVAULT edge server records all 26 channels on one GPS-disciplined time base, and SENSE-AI turns them into natural frequencies, damping, fatigue damage and foundation rotation, every ten minutes.

The nodes attach to tower steel with magnet mounts and the strain gauges are bonded to the inner shell, with no drilling or welding on the tower. Data and alarms stay on site and keep running through communication outages; the cloud is a copy. The alarm never waits for the internet.

Sensors, server, display, communications and software come from one supplier and are designed, programmed and manufactured in Roseville, California. The standard one-tower configuration is $19,999 including shipment, with the SENSE-AI license, remote commissioning and online training included.

THE SYSTEM AT A GLANCE

Sensors	8 MODALINK-PRO nodes, 4 digital strain gauges
Channels	18 acceleration, 4 tilt, 4 strain
Timing	GPS-disciplined, one time base
Server	QUAKEVAULT at the tower base, 4 TB SSD
Display	QUAKEALERT® 14" in the control room
Software	SENSE-AI, perpetual license, included
Cloud	First year included
Price	$19,999 · shipment included

WHAT THE OPERATOR GETS

- ✓ Natural frequencies and damping every 10 minutes
- ✓ Fatigue damage from measured strain
- ✓ Foundation and tower tilt to 0.001°
- ✓ Earthquake records and post-event checks
- ✓ Alarms on site, on the display, by SMS and e-mail
- ✓ Daily, weekly and event PDF reports

THE CHALLENGE

A wind turbine tower is a slender, lightly damped steel cantilever carrying a rotating mass at its top. Fatigue sets its life, bolts and foundation set its stiffness, and the distance between its natural frequencies and the rotor sets its margin.

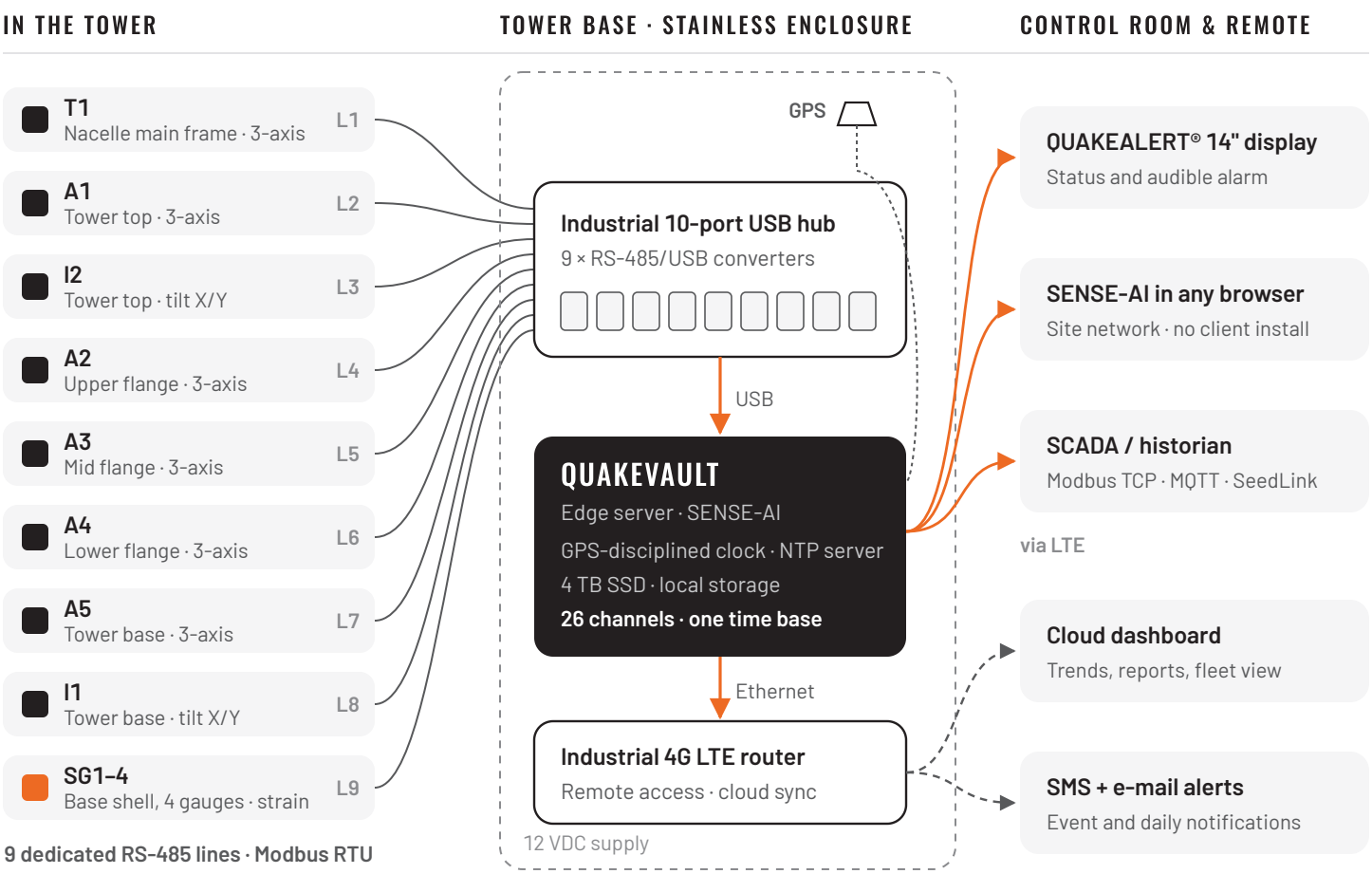
RISK	WHAT CHANGES FIRST	WHAT SENSE-AI MEASURES
Bolted flanges lose preload	Joint stiffness drops; the 1st bending frequency falls slightly and the mode shape kinks at the flange level.	Frequency trend against a temperature-aware baseline; mode-shape change at A2, A3 and A4.
Foundation and grout degrade	Grout cracking, anchor relaxation or soil softening add permanent base rotation and lower f1.	Base tilt I1 to 0.001°, separated from daily thermal swings; f1 trend.
Fatigue at the base and welds	Every revolution, gust and stop adds stress cycles at the door opening and base-flange weld.	Rainflow counting of measured strain, DEL and Miner sum on the S-N curve.
Resonance with the rotor	A soft-stiff tower keeps f1 between 1P and 3P. Stiffness loss or a new speed range can erode that margin.	Measured modes on the Campbell diagram with live 1P and 3P margins.
Lifetime extension	Turbines near their design life need evidence that the structure has margin left.	Measured load spectrum and damage to support lifetime-extension assessments and OEM or certifier reviews.
Earthquakes	In seismic regions an earthquake adds a load case the tower was not checked for in operation.	Strong-motion records at base and top; automatic post-event modal check.

FROM DESIGN ASSUMPTIONS TO MEASURED EVIDENCE

QUANTITY	DESIGN BASIS	WITH SENSE-AI
Natural frequencies	Finite-element estimate with assumed foundation stiffness	✓ Identified every 10 minutes and trended against a baseline
Fatigue loads	Simulated design load spectrum	✓ Rainflow-counted from measured strain at the base
Foundation	Assumed rotational stiffness	✓ Measured base rotation, 0.001° resolution
Earthquakes	Not recorded at the turbine	✓ Strong-motion record and post-event modal check

THE QUAKE SERIES SOLUTION

Every sensor has its own RS-485 line into a QUAKEVAULT edge server at the tower base. One GPS-disciplined clock stamps all 26 channels, so the nacelle, every flange level and the foundation are compared sample by sample.



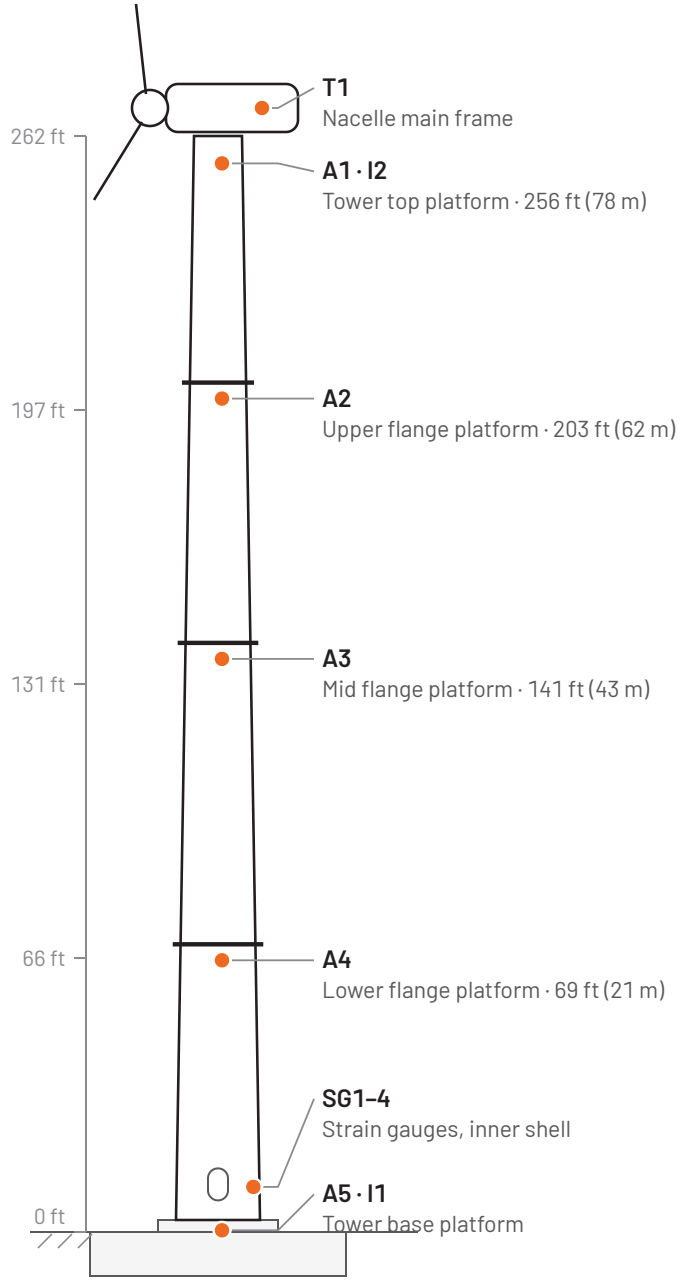
CHANNELS

ONE TIME BASE

MEASUREMENT	SENSORS	LAYOUT	CHANNELS
Acceleration	6 MODALINK-PRO nodes: T1, A1–A5	6 × 3	18
Tilt	2 MODALINK-PRO nodes as biaxial inclinometers: I1, I2	2 × 2	4
Strain	4 Modbus digital strain gauges: SG1–SG4	4 × 1	4
Total			**26**

SENSOR LAYOUT

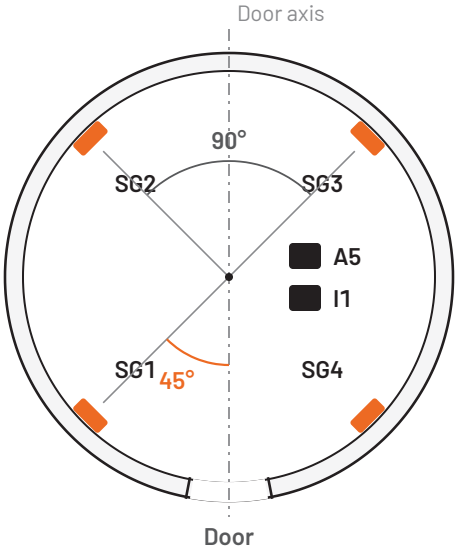
Six measurement levels from the nacelle to the foundation give the first and second bending modes in both directions; the base section adds bending strain and foundation rotation.



Typical 262 ft (80 m) steel tower with three bolted flanges

BASE SECTION · PLAN

10 ft (3 m) above the base flange

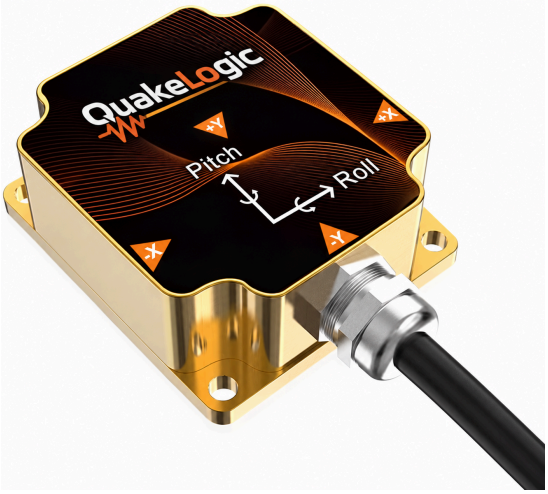


- ✓ **T1** on the nacelle main frame, subject to OEM approval; the yaw platform is the alternative.
- ✓ **A1 to A5** on tower steel at the top, the three flange levels and the base, held by magnet mounts.
- ✓ **I1** at the base platform reads foundation rotation; **I2** at the top reads tower-top tilt.
- ✓ **SG1 to SG4** bonded to the inner shell 10 ft (3 m) above the base flange, 90° apart and 45° off the door axis, clear of the door-opening stress field.
- ✓ Each node has a dedicated RS-485 line (L1 to L8). The four gauges share L9 on separate Modbus addresses.

HARDWARE

MODALINK-PRO SENSOR NODE

8 PER TOWER · 6 TRIAXIAL, 2 INCLINOMETERS



MODALINK-PRO with its 15 m (49 ft) factory-terminated cable. Magnet mount, plug-and-play, no soldering.

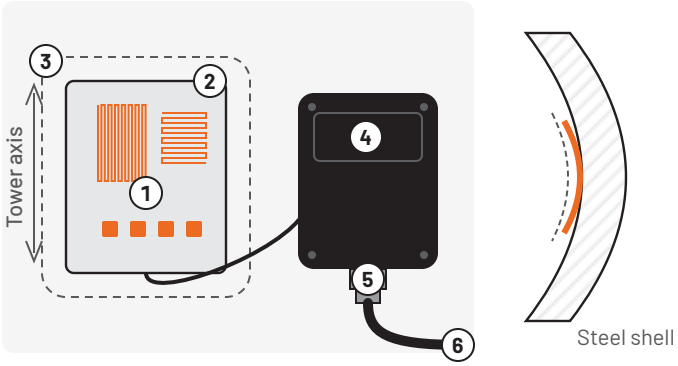
Measured	3-axis acceleration, angular rate, X/Y tilt, magnetic field
Acceleration range	±2 g
Bias stability (10 s)	X/Y 3.5 µg · Z 5 µg
Allan bias instability	X/Y 1.5 µg · Z 3 µg
Temperature drift	±0.056 mg/°F (±0.1 mg/°C)
Sampling	2 kHz internal · digital low-pass 5–256 Hz · output up to 200 Hz per axis
Tilt accuracy	0.001° X/Y · temperature drift ±0.05°
Processor · interface	32-bit · Modbus RS-485
Power	5–36 VDC, < 30 mA
Housing	Aluminium, IP67
Mounting	Magnet mount · no drilling or welding
Size · weight	1.85 × 1.46 × 0.79 in · 1.9 oz (53 g)
Operating temperature	–40 to +185 °F (–40 to +85 °C)
Cable	15 m (49 ft), factory-terminated

MODBUS DIGITAL STRAIN GAUGE

4 PER TOWER · TOWER BASE

FRONT VIEW · ON INNER SHELL

SECTION A–A



1. Foil full bridge
2. Stainless carrier
3. Bonded and sealed coat
4. 24-bit digitiser
5. Cable gland
6. RS-485 to QUAKEVAULT

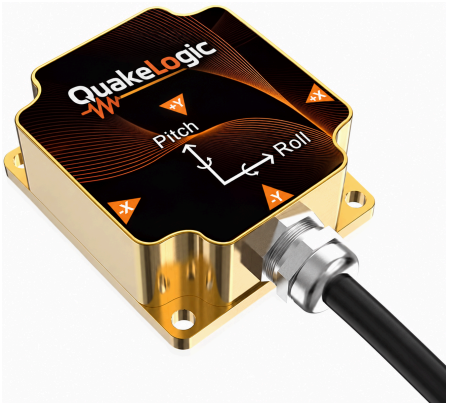
Sensing element	Foil strain-gauge bridge on a stainless carrier matched to steel
Digitiser	24-bit (16 million counts), programmable digital filter
Rate	Up to 500 readings/s
Interface	Modbus RTU over RS-485
Operating temperature	–40 to +185 °F (–40 to +85 °C)
Installation	Bonded and sealed to the inner shell · no drilling or welding

The four gauges sit 90° apart, so SENSE-AI resolves bending about both axes and the mean axial strain from the same section.

QUAKEVAULT EDGE SERVER

1 PER TOWER · TOWER BASE





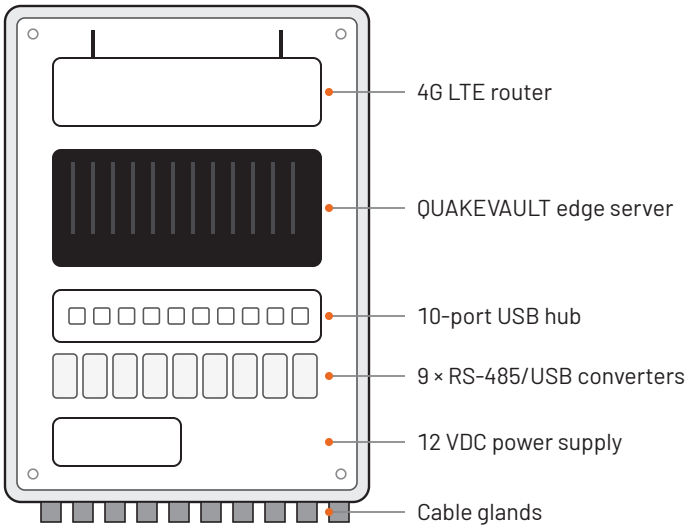
QUAKEVAULT edge server (left), fanless with a sealed aluminium heat-sink housing, and the MODALINK-PRO sensor node it records (right).

Clock	GPS-disciplined, built-in NTP server, GPS antenna and cable
Storage	4 TB SSD on site, years of continuous records; no data loss if the link drops
Sensors	Polls up to 255 Modbus sensors
Software	Runs SENSE-AI; opens in any browser on the site network
Data out	ASCII, CSV, MiniSEED, MAT · FTP, MQTT, Modbus TCP, SeedLink server
Alerts	SMS and e-mail; automatic daily, weekly and event PDF reports
Power	12 VDC

TOWER-BASE ENCLOSURE

STAINLESS STEEL · 12 VDC

ENCLOSURE LAYOUT · DOOR REMOVED



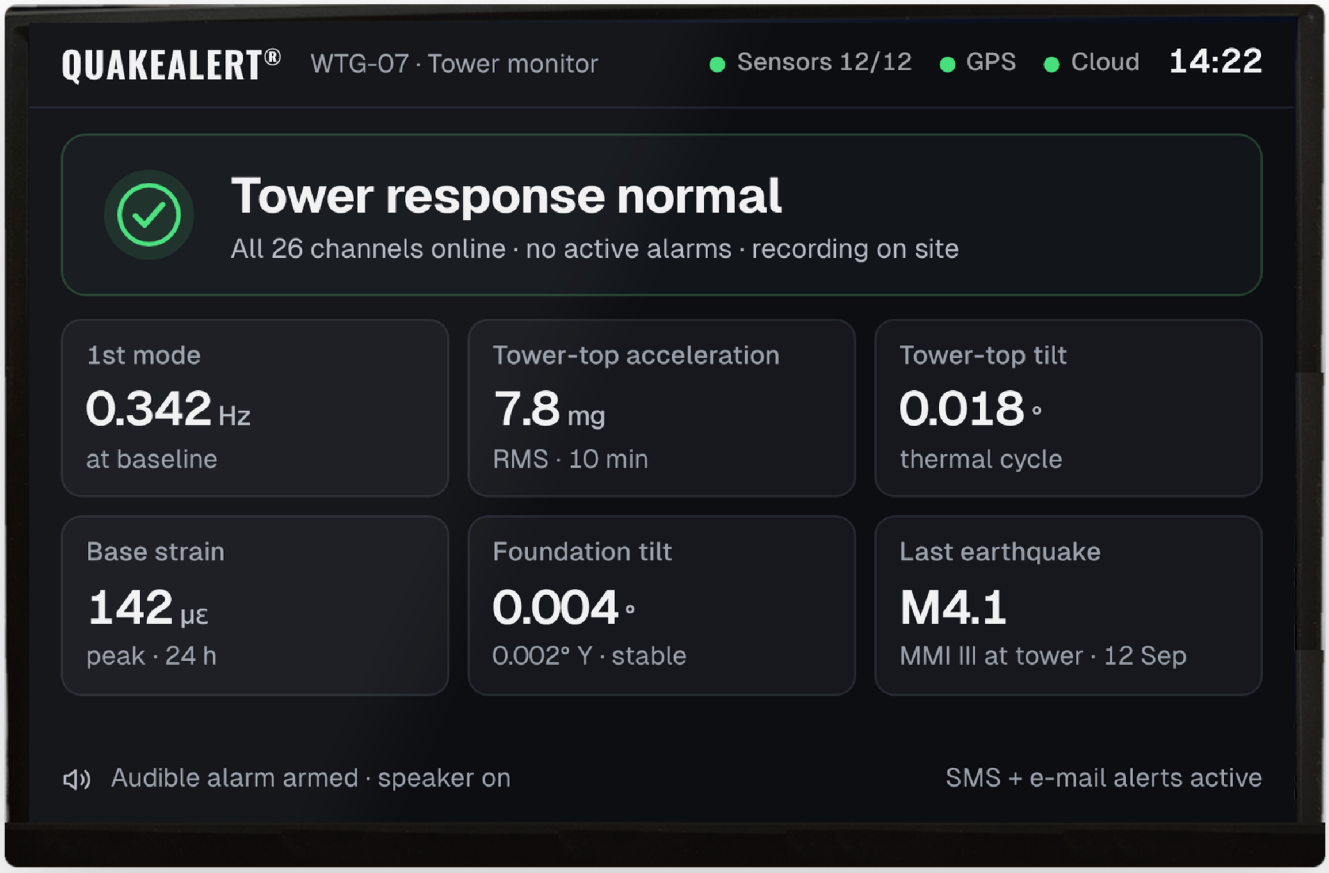
- ✓ Stainless steel enclosure, wall-mounted at the tower base
- ✓ Industrial 10-port USB hub with nine RS-485/USB converters, one per line
- ✓ Industrial 4G LTE router for remote access and cloud sync
- ✓ 12 VDC power supply, connectors and cable glands
- ✓ Factory-wired and tested before shipment

Recording, analysis and alarms all run inside this enclosure. The LTE link carries copies to the cloud and lets QuakeLogic commission and support the system remotely.

QUAKEALERT® 14" TOUCHSCREEN DISPLAY

1 PER TOWER · CONTROL ROOM

A dedicated touchscreen in the control room shows the tower the way an operator needs it: one status line, six numbers and an audible alarm.



QUAKEALERT® 14" with the SENSE-AI wind-turbine screen

- Plain-language tower status that operators read at a glance
- 1st natural frequency, tower-top acceleration and tilt, base strain and foundation tilt
- Last earthquake with its MMI intensity at the tower
- Audible alarm through the built-in speaker
- HDMI out to a control-room wall screen
- Same thresholds drive SMS and e-mail alerts

THE ALARM NEVER WAITS FOR THE INTERNET.

QUAKEVAULT evaluates every threshold on site and drives the display and alarm directly. SMS, e-mail and the cloud receive copies.

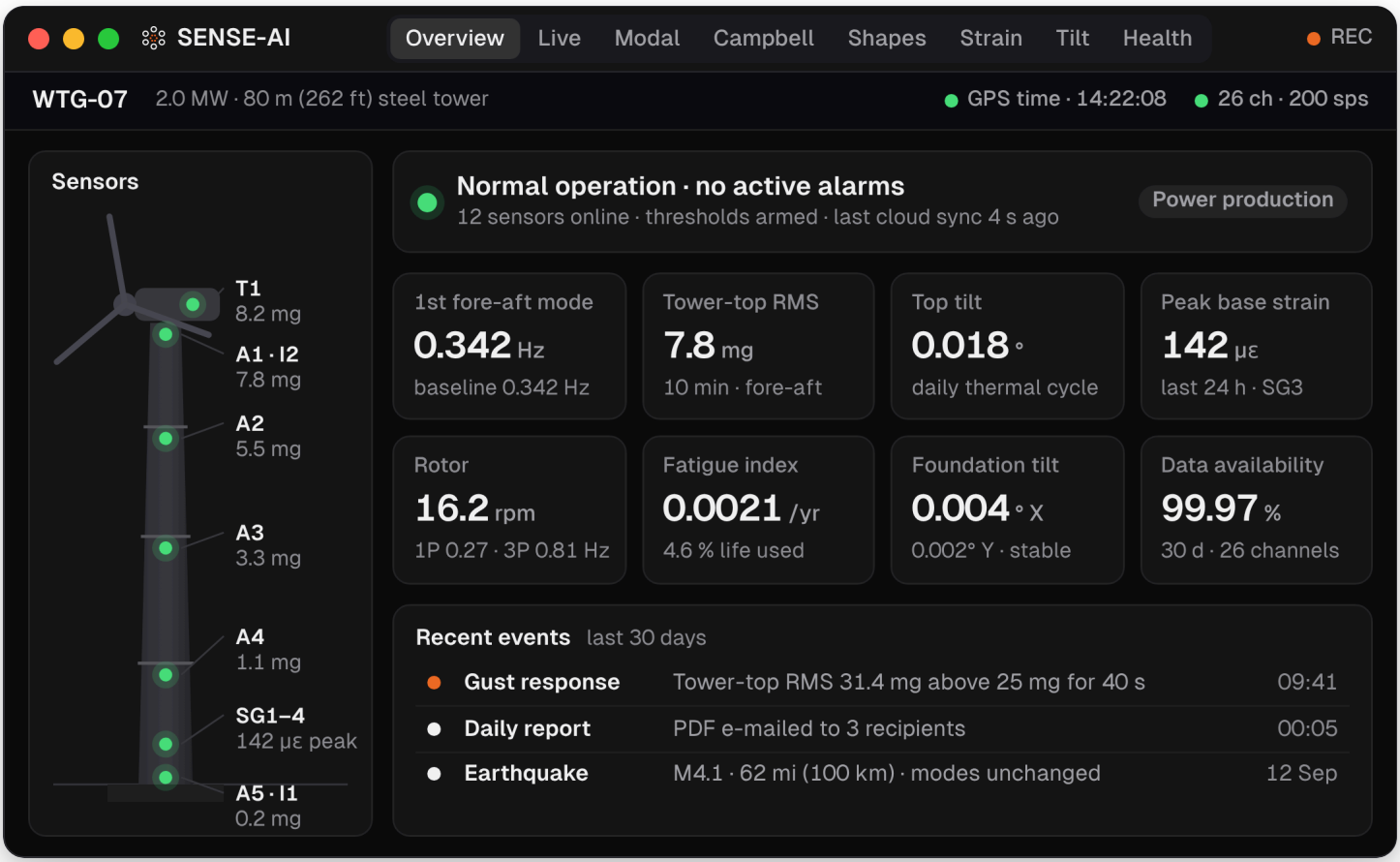
SENSE-AI SOFTWARE

SENSE-AI is QuakeLogic's AI-powered SHM and operational modal analysis software. It runs on QUAKEVAULT, opens in any browser, and is licensed perpetually with free updates.

AI FEATURE	WHAT IT DOES
Automated modal identification	Frequency-domain decomposition of 18 channels every 10 minutes; AI-assisted peak picking with a confidence score
Rotor-harmonic rejection	1P and 3P bands follow the measured rotor speed and are excluded from mode picking
Learned baseline	Learns how frequencies move with temperature and operating state; flags departures outside that band
Fatigue engine	Rainflow counting of base strain, damage-equivalent loads and Miner sum on the S-N curve
Tilt analytics	Separates the daily thermal cycle from permanent foundation rotation
Events and reports	Earthquakes and gusts trigger event reports; daily and weekly PDF reports are automatic

TURBINE OVERVIEW

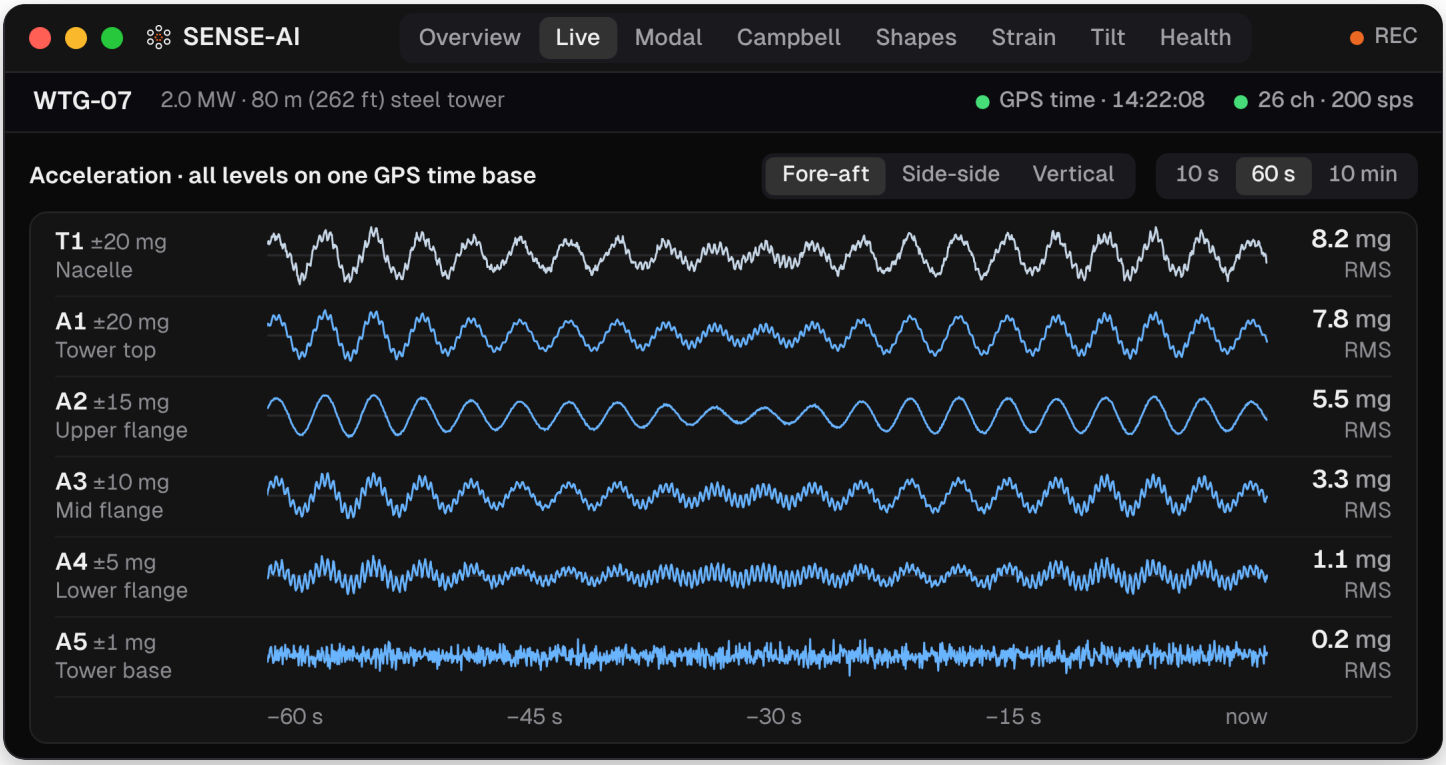
WTG-07 · LIVE



Overview. Sensor status on the tower, eight key values and recent events. Live RMS per level is shown beside each node.

LIVE MONITOR

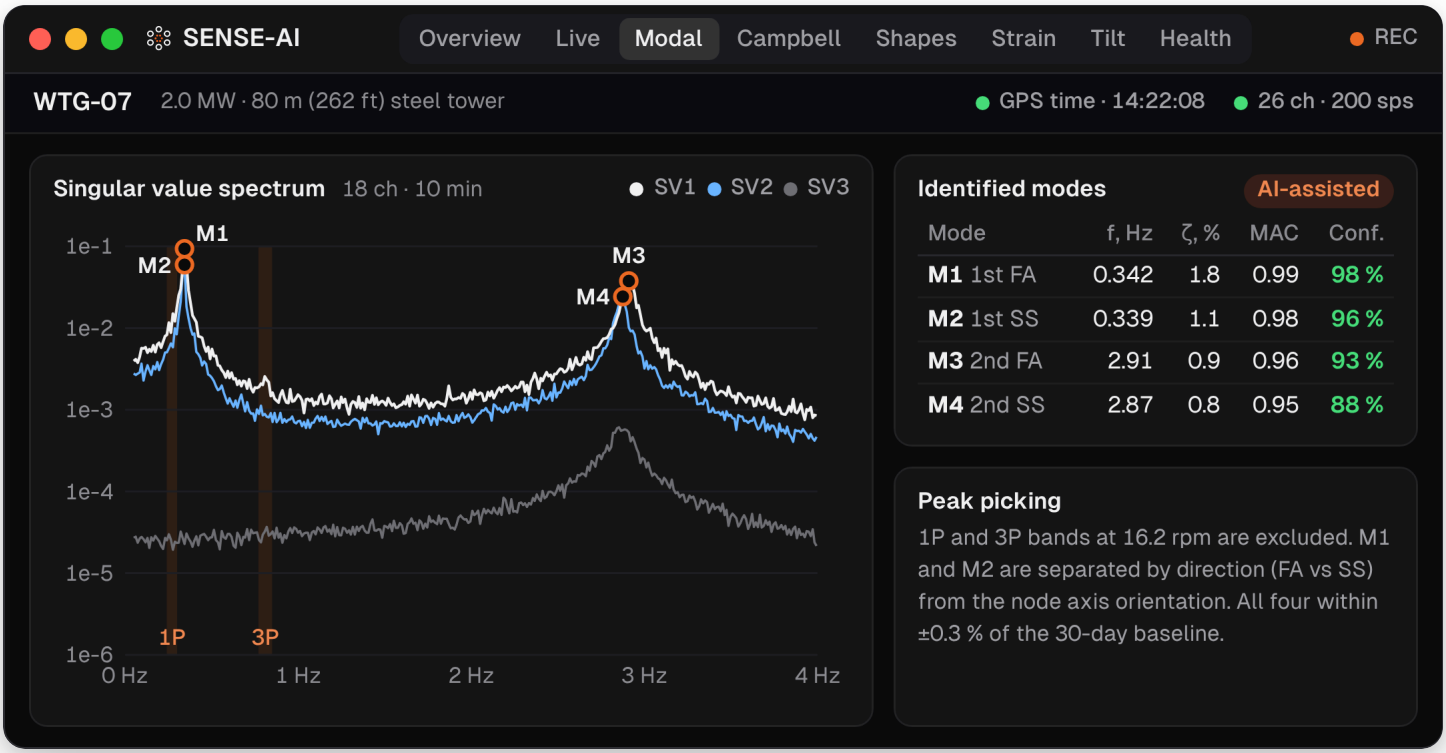
SIX LEVELS · ONE TIME BASE



Live. Fore-aft acceleration at all six levels, sample-aligned. Amplitude grows with height as the first mode predicts.

MODAL IDENTIFICATION

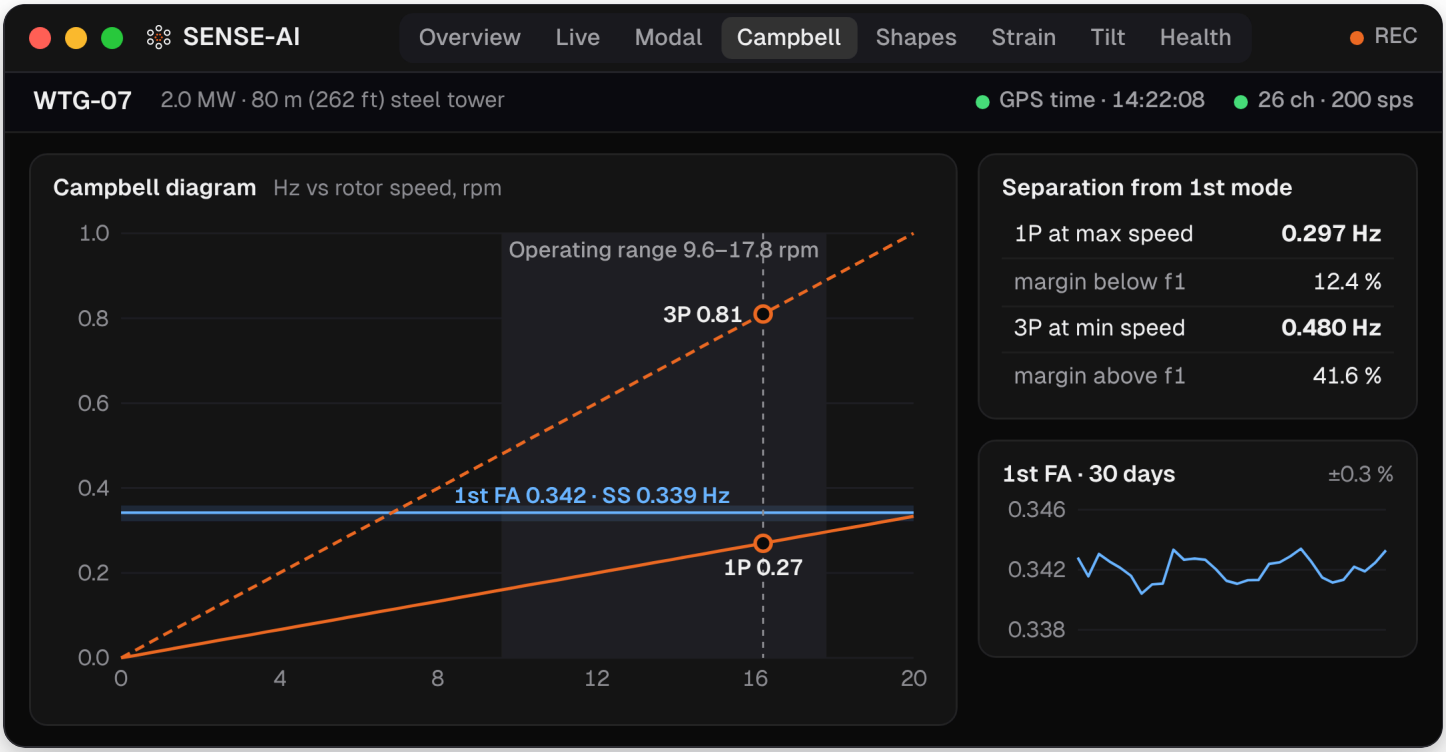
AI-ASSISTED



Modal. Singular-value spectrum with automatic picks of the first and second fore-aft and side-side modes; 1P and 3P bands excluded.

CAMPBELL DIAGRAM

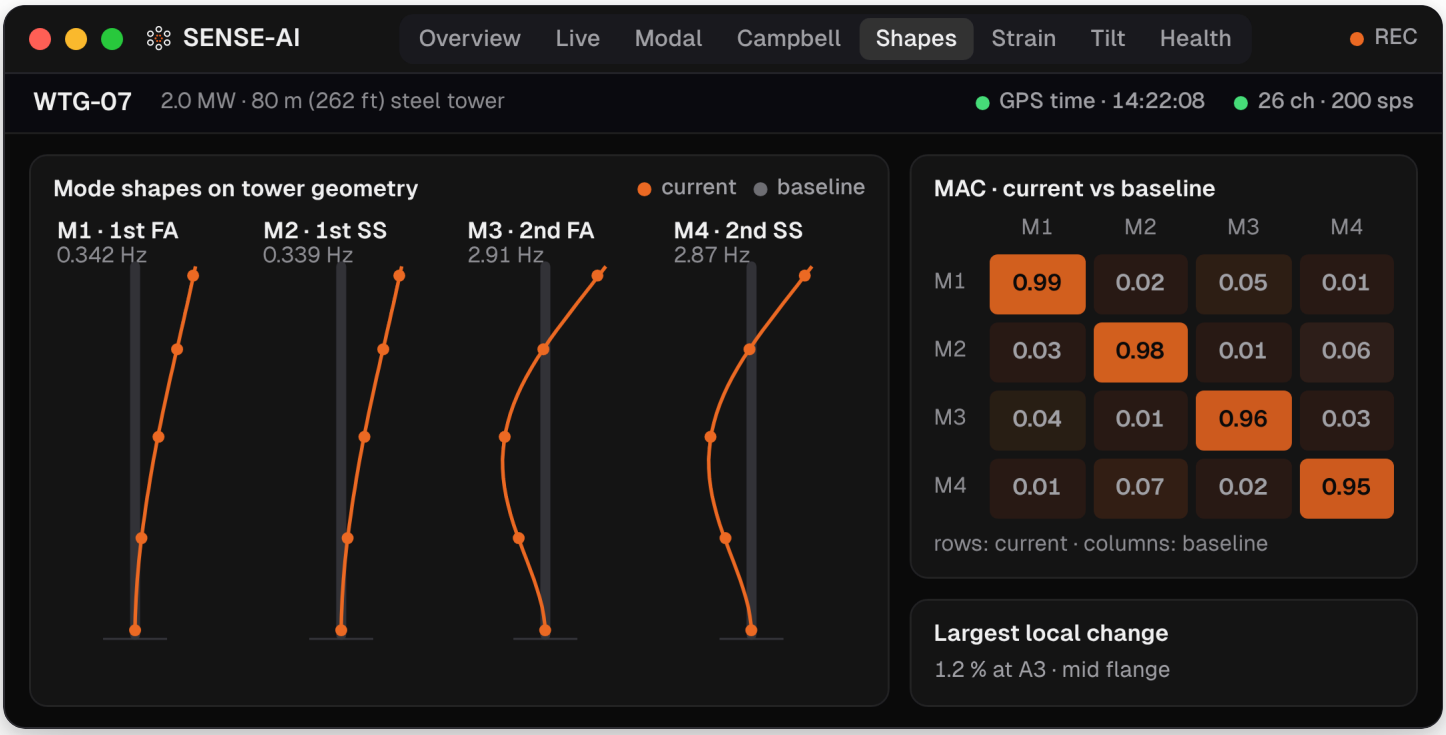
MODES VS ROTOR SPEED



Campbell. The measured 1st modes against 1P and 3P across the 9.6–17.8 rpm operating range, with live separation margins.

MODE SHAPES

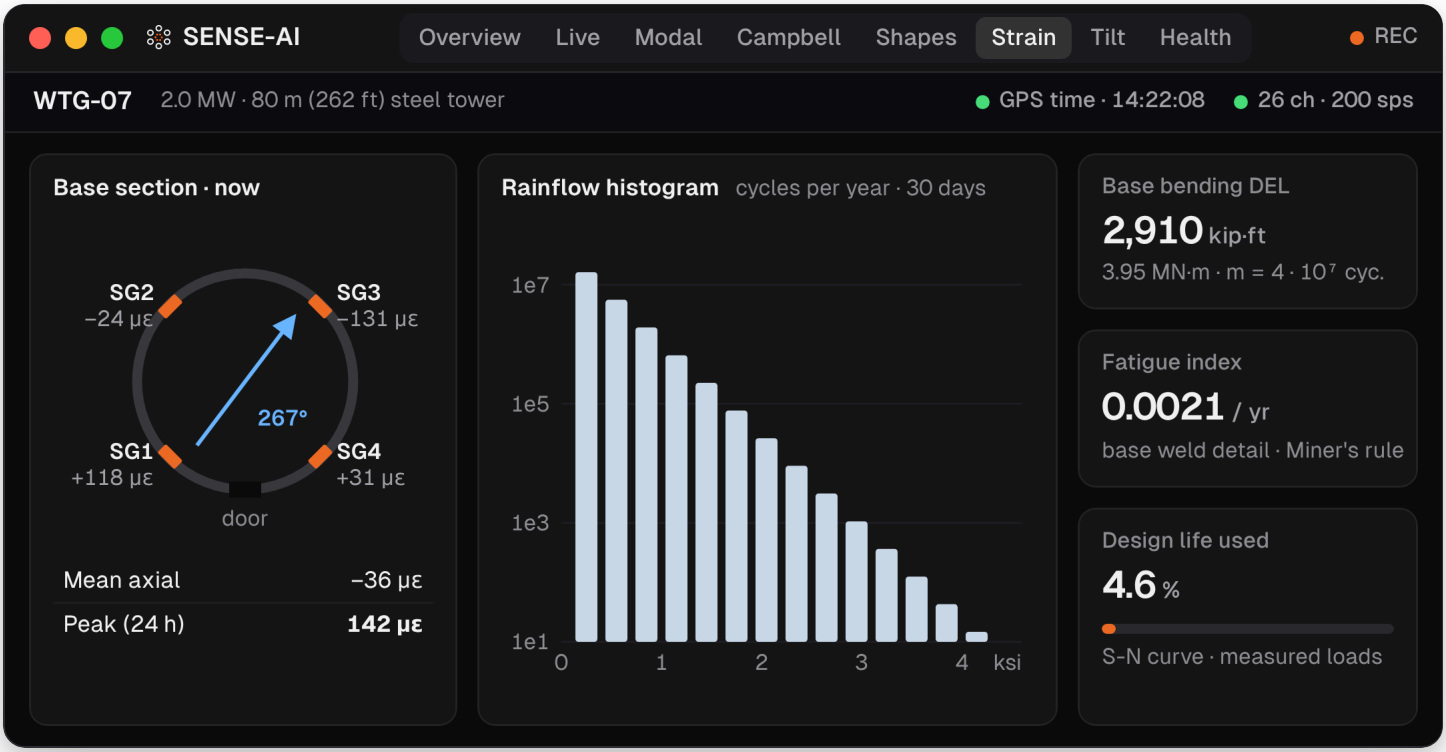
MAC VS BASELINE



Shapes. Measured mode shapes on the tower geometry and the MAC matrix against the commissioning baseline.

STRAIN AND FATIGUE

TOWER BASE



Strain. Four gauges resolve the bending direction; the rainflow histogram feeds the DEL, fatigue index and design life used.

TILT

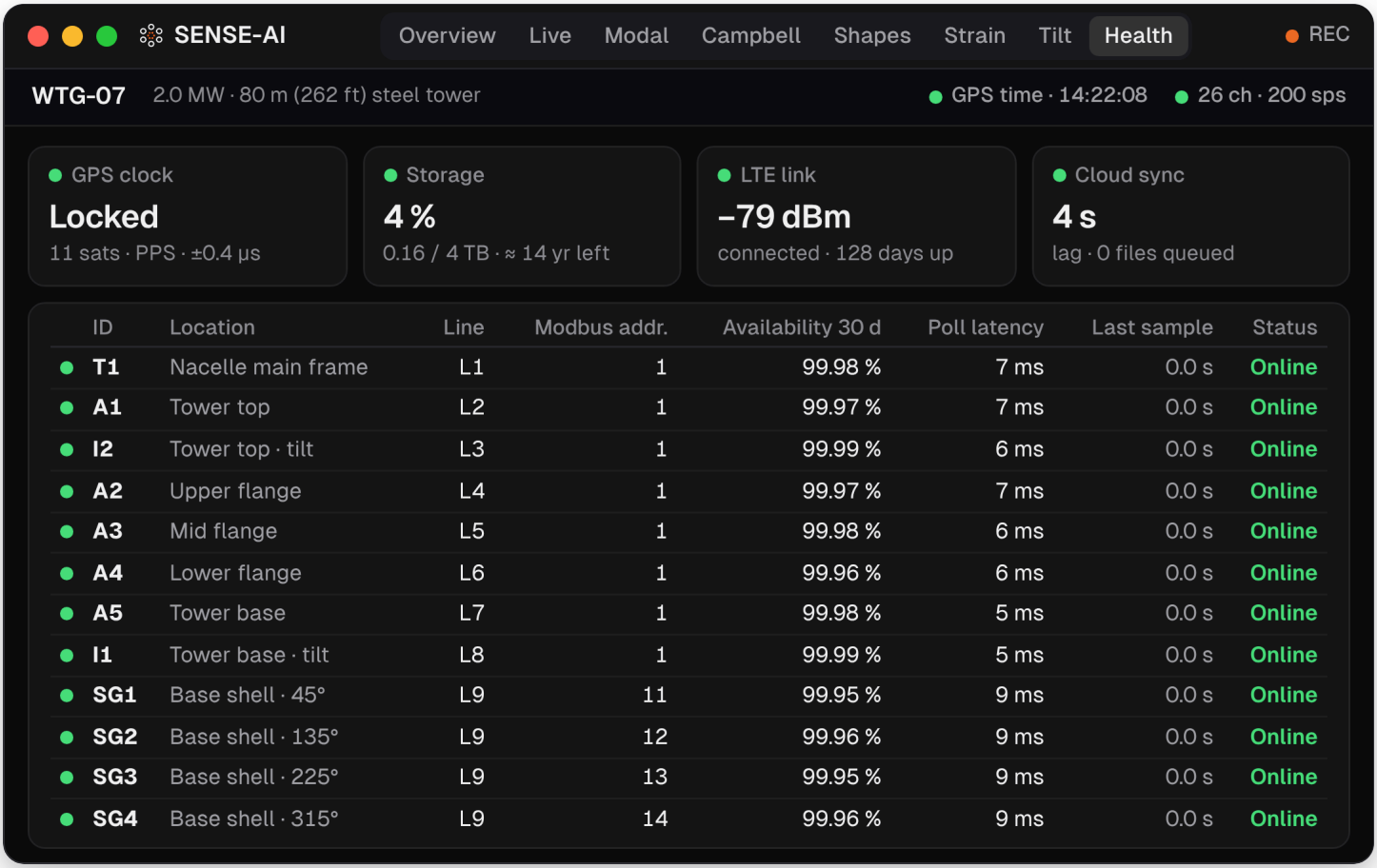
FOUNDATION AND TOWER TOP



Tilt. 90-day foundation rotation, the daily thermal cycle at the tower top and the tilt vector.

SYSTEM HEALTH

SELF-MONITORING



ID	Location	Line	Modbus addr.	Availability 30 d	Poll latency	Last sample	Status
T1	Nacelle main frame	L1	1	99.98 %	7 ms	0.0 s	Online
A1	Tower top	L2	1	99.97 %	7 ms	0.0 s	Online
I2	Tower top · tilt	L3	1	99.99 %	6 ms	0.0 s	Online
A2	Upper flange	L4	1	99.97 %	7 ms	0.0 s	Online
A3	Mid flange	L5	1	99.98 %	6 ms	0.0 s	Online
A4	Lower flange	L6	1	99.96 %	6 ms	0.0 s	Online
A5	Tower base	L7	1	99.98 %	5 ms	0.0 s	Online
I1	Tower base · tilt	L8	1	99.99 %	5 ms	0.0 s	Online
SG1	Base shell · 45°	L9	11	99.95 %	9 ms	0.0 s	Online
SG2	Base shell · 135°	L9	12	99.96 %	9 ms	0.0 s	Online
SG3	Base shell · 225°	L9	13	99.95 %	9 ms	0.0 s	Online
SG4	Base shell · 315°	L9	14	99.96 %	9 ms	0.0 s	Online

Health. Availability, poll latency and status per sensor, with GPS lock, storage, LTE and cloud sync.

DATA OUTPUTS

OPEN FORMATS

Formats	ASCII, CSV, MiniSEED, MAT
Protocols	FTP, MQTT, Modbus TCP to SCADA, SeedLink server
Alerts	SMS and e-mail from on-site thresholds
Access	Any browser on the site network; remote through the LTE router

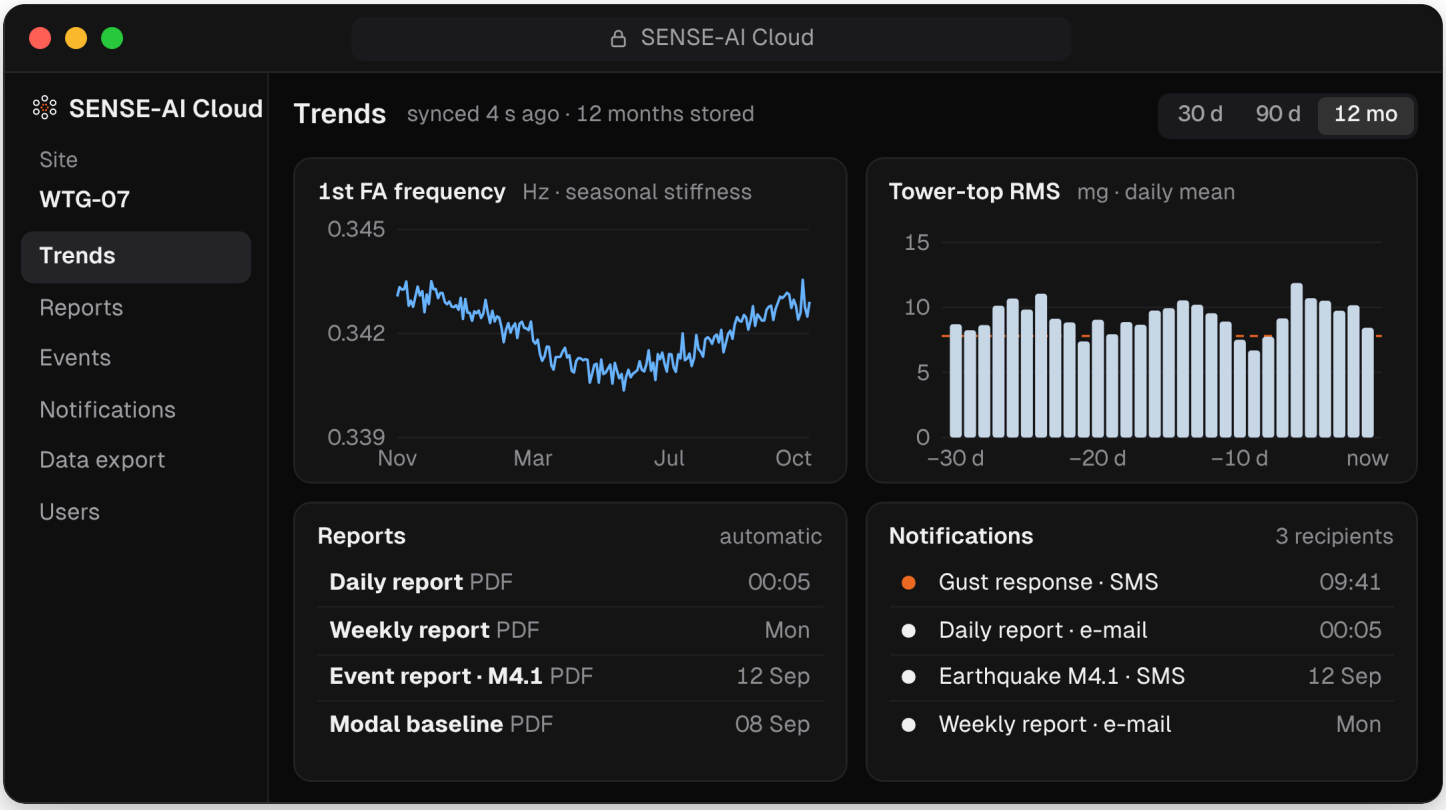
AUTOMATIC REPORTS

PDF

Daily	Modes, damping and MAC; RMS per level; peak strain; tilt; data availability
Weekly	Trends against baseline, Campbell margins, rainflow, DEL and fatigue index
Event	Earthquake or threshold exceedance: records at every level, peaks, MMI at the tower and a post-event modal check

CLOUD DASHBOARD

The cloud dashboard keeps a synchronised copy of trends, reports and notifications for every monitored turbine. The first year is included; it then costs $699 per year, billed annually at the start of each year.



Cloud. Twelve-month frequency trend with its seasonal stiffness cycle, daily tower-top RMS, reports and notifications.

WHY CLOUD

Fleet view	Every monitored turbine in one place, from any browser
Long trends	Seasonal frequency and load trends over months and years
Reports	Daily, weekly and event PDFs archived and shared
Notifications	SMS and e-mail to the people who need them
Data export	Download records in open formats for your own analysis
Off-site copy	A second copy of the data away from the turbine

THE ALARM NEVER WAITS FOR THE INTERNET.

Detection, recording and alarms run on site. If the link drops, QUAKEVAULT keeps everything and syncs when it returns.

PRICE SCHEDULE

Standard one-tower configuration. USD, shipment included.

	ITEM	QTY	UNIT PRICE	AMOUNT
1	**MODALINK-PRO sensor node** Triaxial acceleration and tilt node, magnet mount, 15 m (49 ft) factory-terminated cable	8	$999	$7,992
2	**Modbus digital strain gauge** Foil bridge on stainless carrier, 24-bit digitiser, bonded and sealed	4	$1,091	$4,364
3	**RS-485 extension cable** Nine home runs with service loops	500 m (1,640 ft)	$3.99 / m	$1,995
4	**Industrial 10-port USB hub** DIN-rail mounted	1	$159	$159
5	**QUAKEVAULT edge server** GPS-disciplined clock, NTP server, GPS antenna, 4 TB SSD	1	$2,050	$2,050
6	**Stainless steel server enclosure** Wall-mounted at the tower base, cable glands	1	$295	$295
7	**Industrial 4G LTE router** Remote access and cloud sync	1	$495	$495
8	**QUAKEALERT® 14" touchscreen display** Control-room display, speaker, HDMI out	1	$1,399	$1,399
9	**SENSE-AI software, perpetual license** AI-powered SHM and OMA, runs on QUAKEVAULT, free updates	1	Included	Included
10	**Cloud dashboard, year 1** Then $699 per year, billed annually at the start of each year	1	Included	Included
11	**Accessories lot** 9 × RS-485/USB converters, 12 VDC power supply, connectors	1	Included	Included
12	**Shipment** Crated system, freight to the project site	1	$1,250	$1,250
	TOTAL · USD · SHIPMENT INCLUDED			**$19,999**

OPTIONS

PRICED SEPARATELY · NOT IN TOTAL

Extended hardware warranty to 3 years (10 % of hardware, items 1–8: $18,749)	$1,875
On-site installation, commissioning and training: $5,000 travel + $1,500 per day (typically 3–4 days per turbine)	Quoted per site
Each additional turbine	Quoted per project

INSTALLATION, SUPPORT AND TERMS

The system arrives configured and tested. Installation is mechanical work inside the tower; commissioning is done remotely by the engineers who wrote the software.

1	**Survey and approvals**	We review tower drawings and platform levels with you. You obtain OEM approval for the nacelle node and schedule the stoppage.
2	**Factory configuration**	We configure every node, gauge address, line and threshold, and load your tower geometry into SENSE-AI before shipment.
3	**Installation**	Your technicians, or our team as an option, mount the nodes, bond the gauges and run the factory-terminated cables to the enclosure.
4	**Remote commissioning**	Over the LTE link we verify every channel, timing, storage and alarm path, and confirm the display and notifications.
5	**Baseline and training**	The first 30 days build the modal and tilt baseline. Online training covers daily use, reports and alarms.

WARRANTY AND SUPPORT

- ✓ 12-month hardware warranty; extension to 3 years available
- ✓ Lifetime technical support; 24/7 line +1-650-353-6827
- ✓ SENSE-AI perpetual license with free updates
- ✓ Remote commissioning and online training included
- ✓ Repairs: you ship the unit to QuakeLogic; we pay the return shipment

COMMERCIAL TERMS

Delivery	3–4 weeks after receipt of order
Payment	50 % with order, 40 % before shipment, 10 % on commissioning
Validity	90 days from issue
Terms	quakelogic.net/terms-and-conditions
Excluded	Duties and taxes, turbine OEM approvals and stoppage, SIM and data plan, mounting works, on-site installation and training unless ordered. The owner provides a 120/230 VAC outlet at the tower base.

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WHY QUAKELOGIC

We build monitoring systems for structures where the data has to hold up: bridges, tall buildings, public housing and now wind turbine towers.

Certified quality	ISO 9001, ISO 14001 and ISO 45001 certified. California-certified small business. Registered UNGM supplier.
Strong-motion pedigree	Our founder managed the USGS strong-motion network for 11 years and developed the USGS PRISM strong-motion processing software.
Landmark structures	Monitoring software for the 1915 Çanakkale Bridge, the world's longest single-span suspension bridge. Instrumentation and SHM on the Galena Creek Bridge, Nevada.
Tall buildings and fleets	SHM software for the world's tallest concrete building in Kuwait City. 160 public housing buildings instrumented for HDB Singapore.
One supplier	Sensors, server, display, communications and software from one company, designed and built to work together.
Plug-and-play	Factory-terminated cables and pre-configured software. No soldering, no integration project.

We would be glad to adapt this configuration to your turbine model and to quote your fleet.

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Designed, Software Development and Manufactured in Roseville, California

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