StructureIQ

Domed Stadium Structural Monitoring

APPLICATION NOTE

Reduce Risk of Domed Structure Failures

Executive Summary

Structural Integrity of Domed Stadiums
Domed stadiums present unique structural complexities that exceed those of standard vertical construction. These massive long-span structures are sensitive to environmental stressors (especially during construction) — such as non-uniform loads and wind uplift— and undergo dynamic stress from suspended concert rigging and acoustic vibrations. Due to their scale and height, critical components like tension rings, truss connections, and membrane fabrics are often difficult to access, making degradation like fatigue cracking or bolt corrosion hard to detect during routine visual inspections.

StructureIQ offers a proactive solution: a scalable, wireless Structural Health Monitoring (SHM) system providing a continuous, data-driven view of the dome's structural performance. By detecting early warning signs of deflection anomalies, thermal stress, and load redistribution in real-time, StructureIQ empowers facility managers to shift from reactive repairs to predictive maintenance— ensuring the safety of high-capacity events and extending the lifespan of the asset.

The Challenge: Silent Threats to Large-Span Domed Stadiums

The challenge of maintaining large-span domed stadiums stems from silent threats leading to structural failures, typically due to hidden stress factors. Key issues include:

- **Construction stage:** Achieving precise design conditions is most vulnerable during construction; the incomplete structure navigates complex load-transfer events differing from the final model. It is critical to monitor the over all domed structure during this phase.
- **Run-to-Failure Trap:** Traditional visual inspections are dangerous and risky for engineers, expensive and infrequent, creating blind spots that allow critical issues to develop unnoticed.
- **Corrosion & Aging:** Moisture accumulation accelerates corrosion in steel components, in salty environments caused by proximity to the sea. These are often hidden by insulation, compromising load-bearing capacity before it becomes visible.

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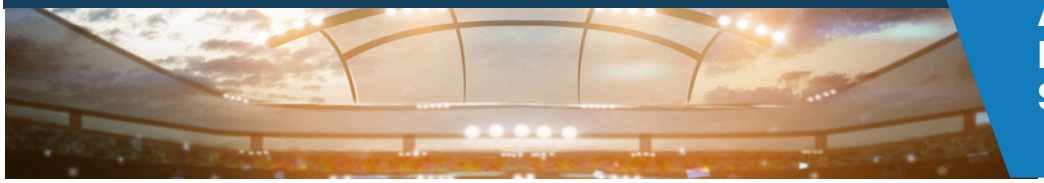


StructureIQ Solution offers continuous, data-driven risk assessment

- **Structural Instability**: Monitors vibration and accelerometry to detect issues from weakened joints caused by strong winds or seismic activity
- **Sudden Event Response:** High-frequency sampling during seismic events assesses structural impact.

Real-World Failures: The Case for Continuous Structural Monitoring

The Hartford Civic Center (USA) — The Failure of Verification

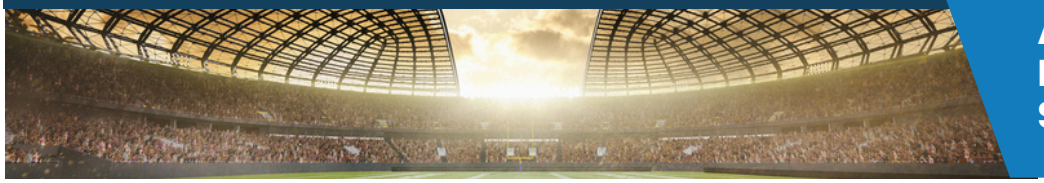
- Incident: The total collapse of the 2.4-acre space frame roof just hours after a basketball game attended by 5,000 people.
- Root Cause: "**Design deficiencies**" and "underestimation of dead load" caused massive, progressive buckling of the truss members that went unnoticed during visual checks.
- Relevance: The roof exhibited significant deflection (sagging) during construction—a clear "silent threat" that wireless tilt and strain sensors would have detected immediately, preventing the "run-to-failure" scenario.

The Sultan Mizan Zainal Abidin Stadium (Malaysia) — The Failure of Geometry

- Incident: The collapse of the massive steel space-frame roof just one year after the stadium opened, destroying the main grandstand and seating bowl.
- Root Cause: "**Inadequate design**" and "misalignment of steel members" during assembly caused the truss geometry to shift, leading to buckling that went undetected.
- Relevance: Wireless tilt, strain sensors, and accelerometers would have identified anomalous movements and would have identified the "buckling" and progressive deformation of the roof trusses early, alerting engineers that the structure was deviating from its designed geometry before it reached a critical failure point.

The Hubert H. Humphrey Metrodome (USA) — The Failure of Environmental Response

- Incident: The complete collapse of the air-supported fiberglass roof in 2010 following a storm.
- Root Cause: " excessive load" and "low internal pressure" led to a tear in the fabric that propagated rapidly (Risk Management Magazine).
- Relevance: A lack of vibration monitoring prevented operators from identifying specific stress concentrations or triggering rapid-melt systems before the fabric's failure limit was reached.



APPLICATION NOTE: Reduce Risk of Domed Structure Failures

Implementation Strategy: Comprehensive High-Resolution Array

For critical large-span venues under construction or aging stadiums requiring precise damage localization, StructureIQ recommends a high sensor density. This approach mirrors high-fidelity data collection methods proven necessary for complex 3D geometries, ensuring no critical structural element—however inaccessible—goes unmonitored.

Domed Stadium Roof

The StructureIQ High-Resolution Deployment Schematic in Figure 1 below illustrates a high-density deployment on a long-span dome roof. Wireless sensors are attached to critical tension ring segments and primary truss chords to detect localized vibration or displacement caused by connection fatigue or uneven rigging loads. These distributed array of tri-axial accelerometers across the dome's crown and perimeter monitors for asymmetric wind uplift and excessive global deflection during high-load events.

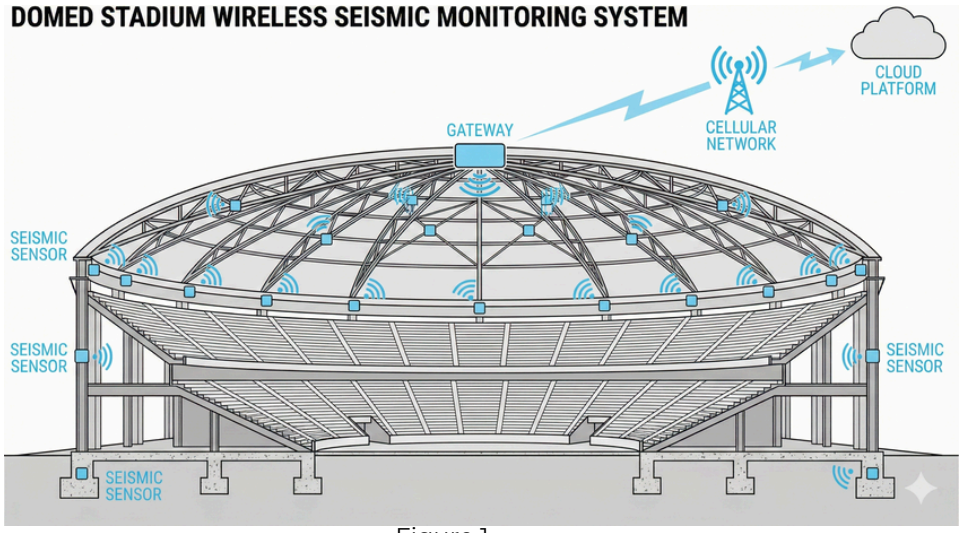


Figure 1.

The StructureIQ SaaS Platform

StructureIQ offers secure transmission of high-resolution sensor data to a cloud-based dashboard, converting raw data into actionable intelligence without the need for complex IT infrastructure. Key features include:

High -resolution Sensor

- **Zero-Touch Cellular Connectivity:** Sensors with low-power cellular connectivity (LTE-M/NB-IoT) for easy deployment in remote areas.
- **End-to-End Security:** Encrypted data transmission over cellular networks and secure, SOC 2 compliant cloud hosting.
- **Actionable Dashboard:** Centralized view of bridge health with:
  - Real-Time Visualization of loads and vibrations.
  - Automated Alerts for safety threshold breaches.

SaaS Dashboards

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Benefits & ROI: The Value of High-Fidelity Data in Domed Venues

Switching to a high-resolution StructureIQ sensor array transforms SHM from a passive alarm into a strategic asset management tool for complex domed structures.

- **Risk Mitigation During Construction & Assembly:** The most vulnerable phase for a long-span dome is assembly. Installing SHM sensors during construction provides real-time validation as temporary supports are removed and loads transfer to the permanent structure. This ensures that "as-built" geometry matches design specifications.

- **Precision Maintenance:** A fully instrumented structure can tell engineers exactly where a problem exists—down to specific truss nodes. This precise localization directs expensive rope-access crews immediately to the affected zone.

- **Liability Shield & Due Diligence:** In massive public events, uncertainty is a significant liability. In severe weather, seismic activity, or heavy rigging loads, a continuous data stream provides an immutable digital audit trail. This proof of structural performance demonstrates due diligence to insurers, regulators, and the public.

- **Asset Value Protection & Life Extension:** Domed stadiums represent enormous investments designed for multi-decade lifespans. Continuous monitoring allows owners to maximize ROI by managing long-term trends like environmental degradation and cumulative fatigue. Identifying issues early defers major capital expenditures and extends the life of the venue.

Conclusion

Large-span domed stadiums are complex architectural marvels facing unique, often invisible risks throughout their lifecycles. As the Hartford Civic Center and The Malaysian stadium collapses illustrated, relying solely on difficult and infrequent visual inspections allows "silent" threats, from construction deviations to environmental loading, to go undetected until catastrophic failure. StructureIQ bridges this critical gap. By deploying a high-resolution wireless sensor network, facility owners give a "voice" to their immense roof structures, transitioning from reactive uncertainty to data-driven assurance, ensuring these iconic venues remain safe, functional, and enduring.

References

- Hubert H. Humphrey Metrodome: "Metrodome Roof Collapses Under Weight Of Snow." WJON, December 12, 2010. https://wjon.com/ymetrodome-roof-collapses-under-weight-of-snow/. (Relating to the incident and excessive snow load).
- Hartford Civic Center: "Almost a Tragedy: The Collapse of the Hartford Civic Center." Connecticut History | a CTHumanities Project. https://connecticuthistory.org/almost-a-tragedy-the-collapse-of-the-hartford-civic-center/. (Relating to the incident and underestimation of dead load).
- Sultan Mizan Zainal Abidin Stadium: "Sultan Mizan Zainal Abidin Stadium Roof Collapse." Penn State College of Engineering. https://www.engr.psu.edu/ae/thesis/failures/MKP/failures/failures.wikispaces.com/Sultan_Mizan_Zainal_Abidin_Stadium_Roof_Collapse.html. (Relating to the incident, inadequate design, and improper erection).