

From Volcano Monitoring to Industrial Safety: Enabling Real-Time CH₄ Underwater Observation Through Wireless Acoustic Networks

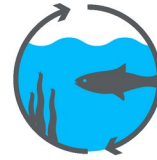
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Monitor CH₄ – Bologna – 9 Luglio 2026



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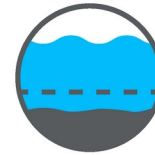
Agenda



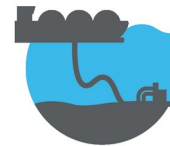
Underwater **Monitoring Challenges**



Wireless multi-hop acoustic networks



INGV field validation in extreme seismic and volcanic



From volcano monitoring **to industrial applications**

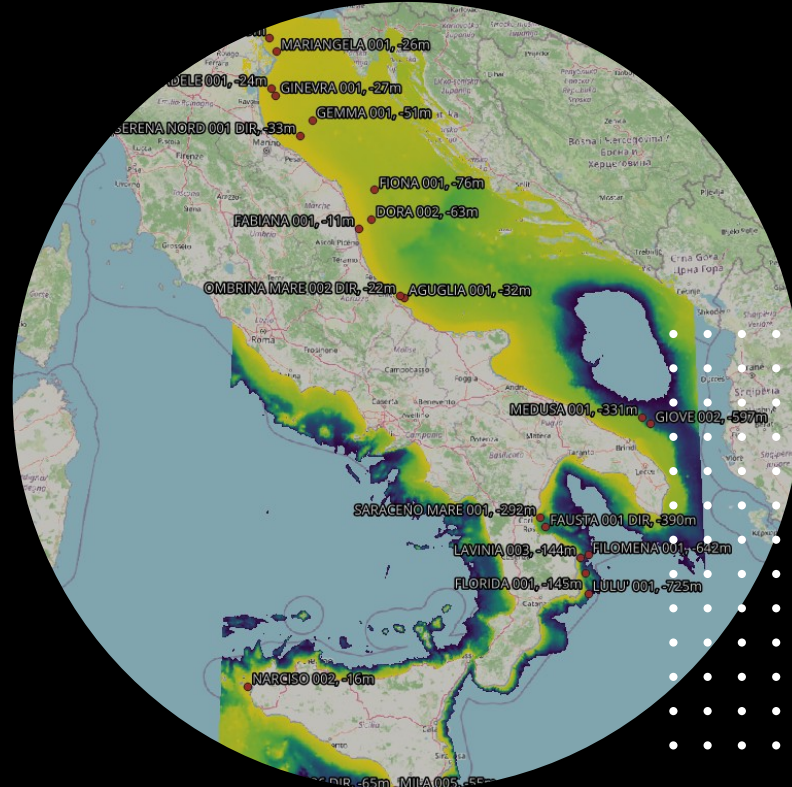
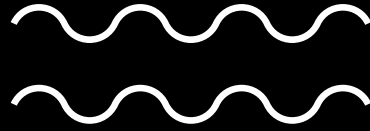


Industrial drivers for CH_4/CO_2 monitoring

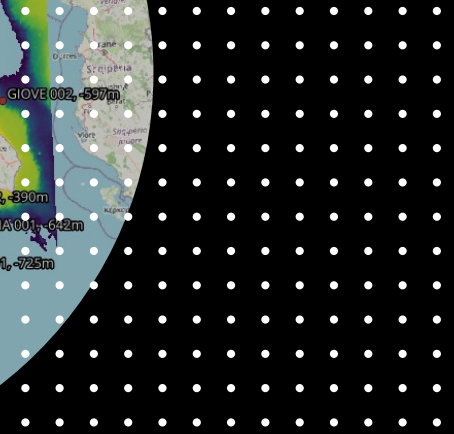


Scalable, **cable-free architectures**

23 Dismissed CH₄ Well- Heads without an owner



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Monitoring in Dynamic & Harsh Environments

- Volcanic **vents**, hydrothermal **turbulence**, **unstable seabed**
- **High temperatures**, **corrosive fluids** (CH_4 , CO_2)
- Risk of **cable degradation** or **failure**
- Need for **flexible**, **reconfigurable** **deployments**
- Need of **continuous real time data**



Mesh Multi-Hop Wireless Real-Time Sensor Agnostic



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1 W CLOUD



2 UNDERWATER DRONE GENERAL PURPOSE MODULE



3 W MICRO



4 WNODE &
WNODE ENHANCED



5 W GATEWAY



6 SMART BUOYS

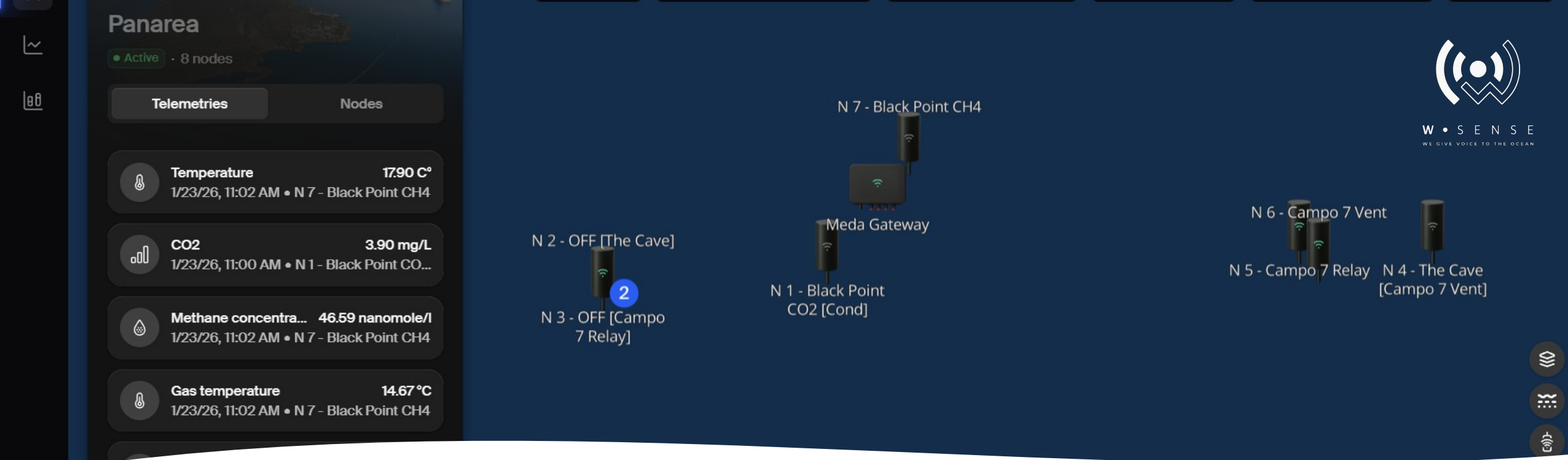


7 UNDERWATER FIBER GATEWAY



INGV Scientific Foundation

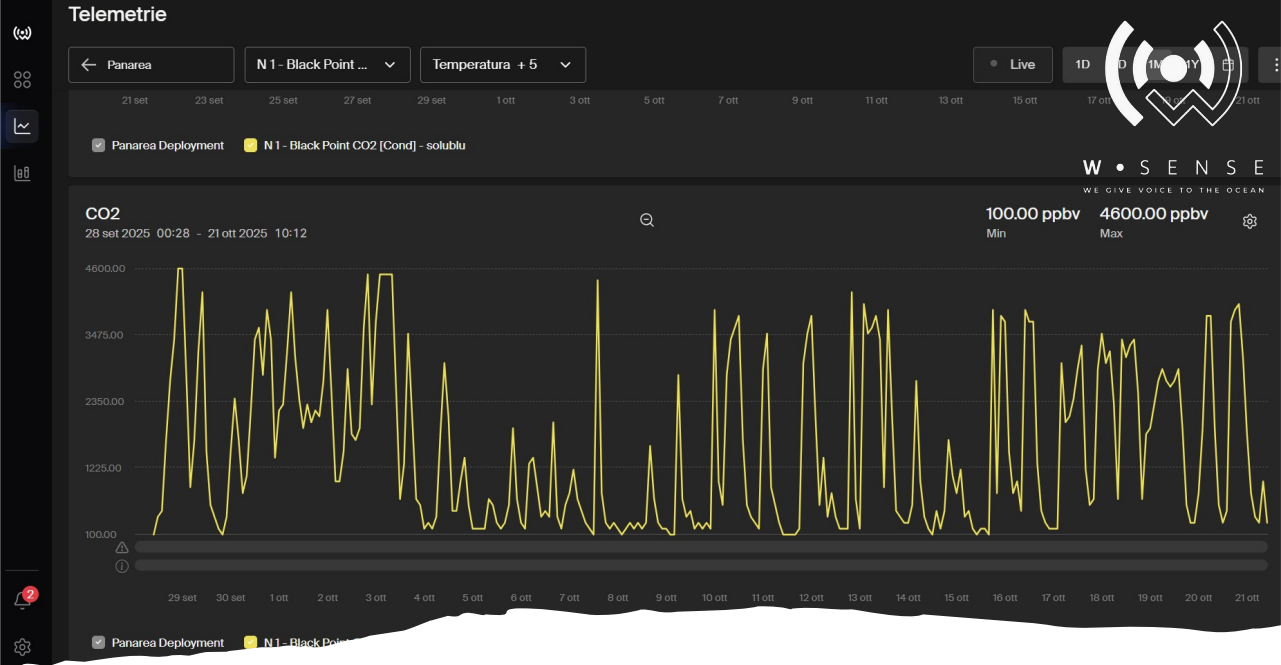
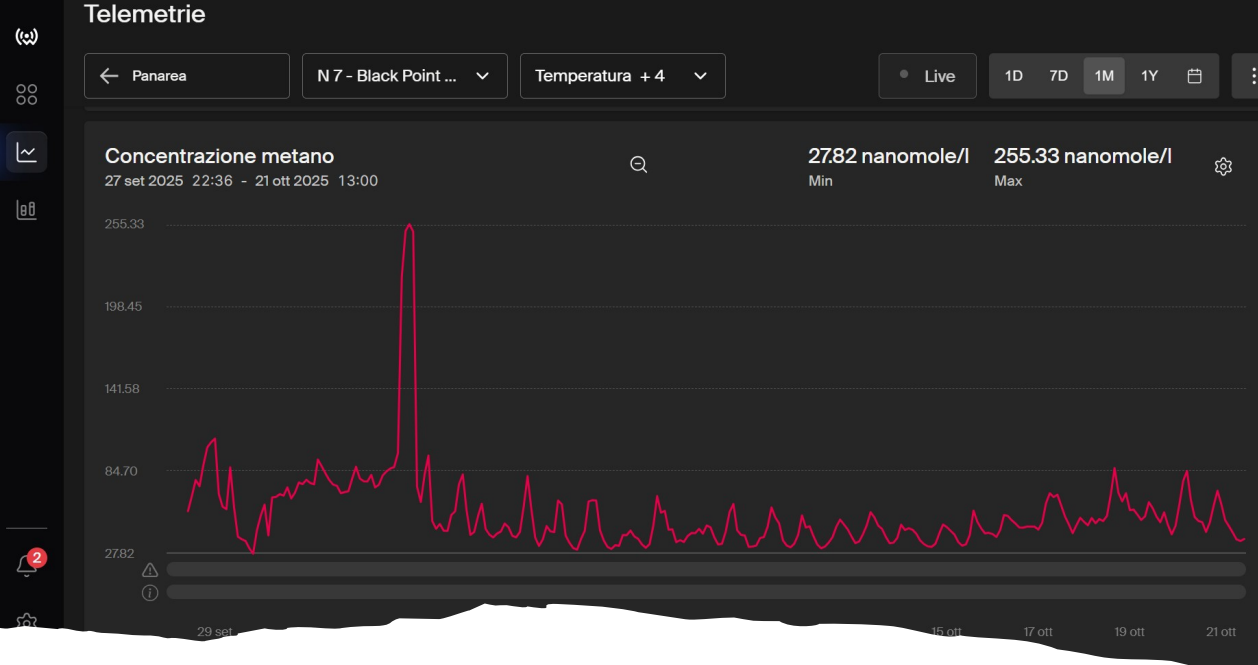
- **PEGASO Seabed Observatory (Panarea)** – multiparametric module in extreme CO_2/CH_4 hydrothermal fields
- **IPANEMA Project** – underwater acoustic infrastructure for natural CO_2 emission monitoring (Panarea & Gulf of Catania)
- **EMSO** - European Multidisciplinary Seafloor and water-column Observatory
- **MACMAP** - A Multidisciplinary Analysis of Climate change indicators in the Mediterranean And Polar regions - Sea acidification offshore Panarea island (Aeolian Arc)



The Challenge of Real-Time Seafloor Observation

- **Long-duration autonomous** operation needed
- **Wide spatial coverage** required
- **Transient events** occur unpredictably

Traditional systems: **costly, fragile, limited scalability**
WSense IoUT: **flexible, sensor agnostic, highly mobile**

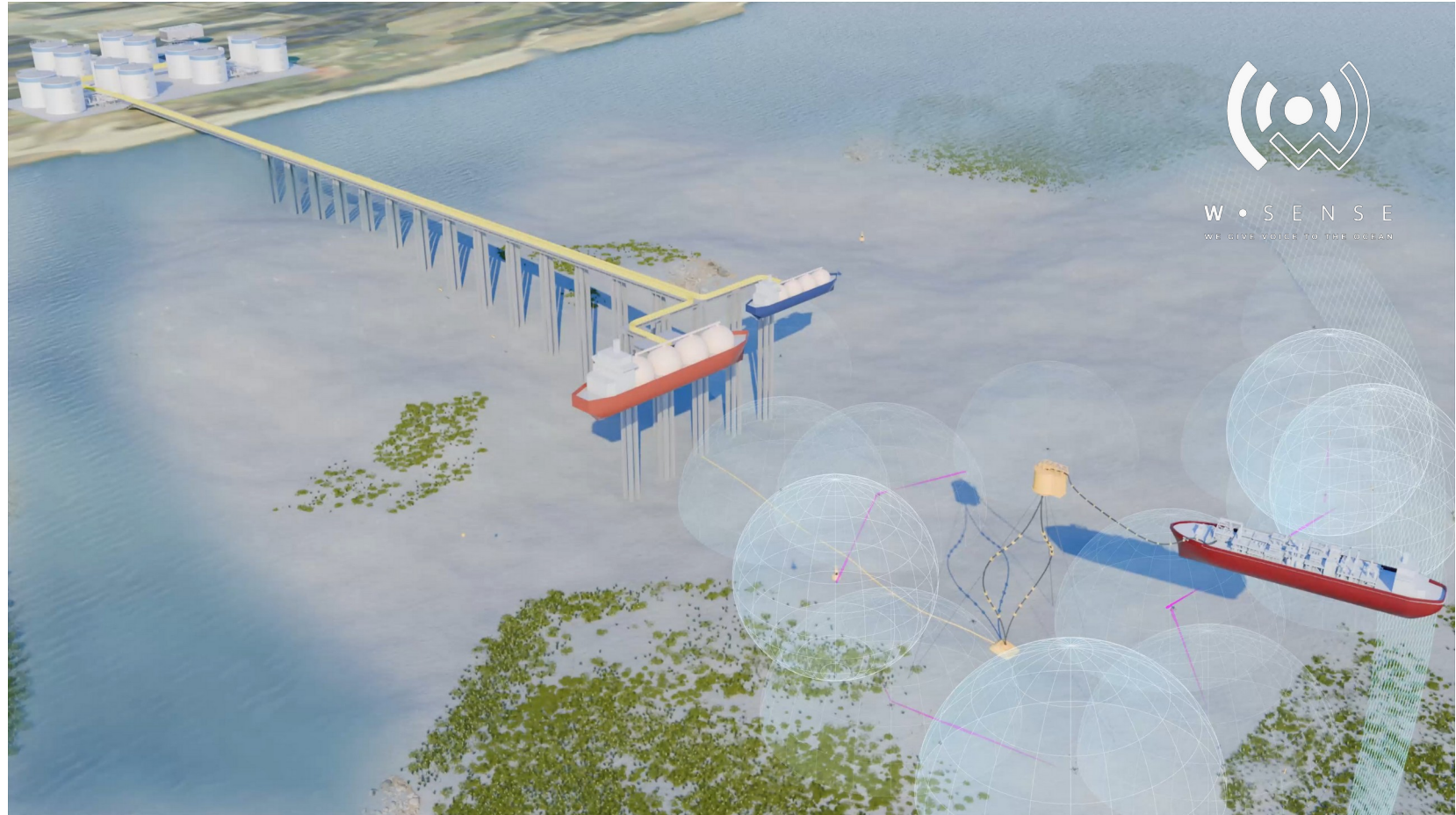


Solution | Mitigating Cabled Infrastructure Challenges in High-Risk Zones

- **Detect environmental anomalies in real time**, before they escalate into critical events.
- **Provide early warning** systems to authorities.
- **Extended monitoring zones:** Capturing environmental shifts across wide underwater areas.
- **Impact on research:** Monitoring conditions to gather critical data for tuning predictive models.

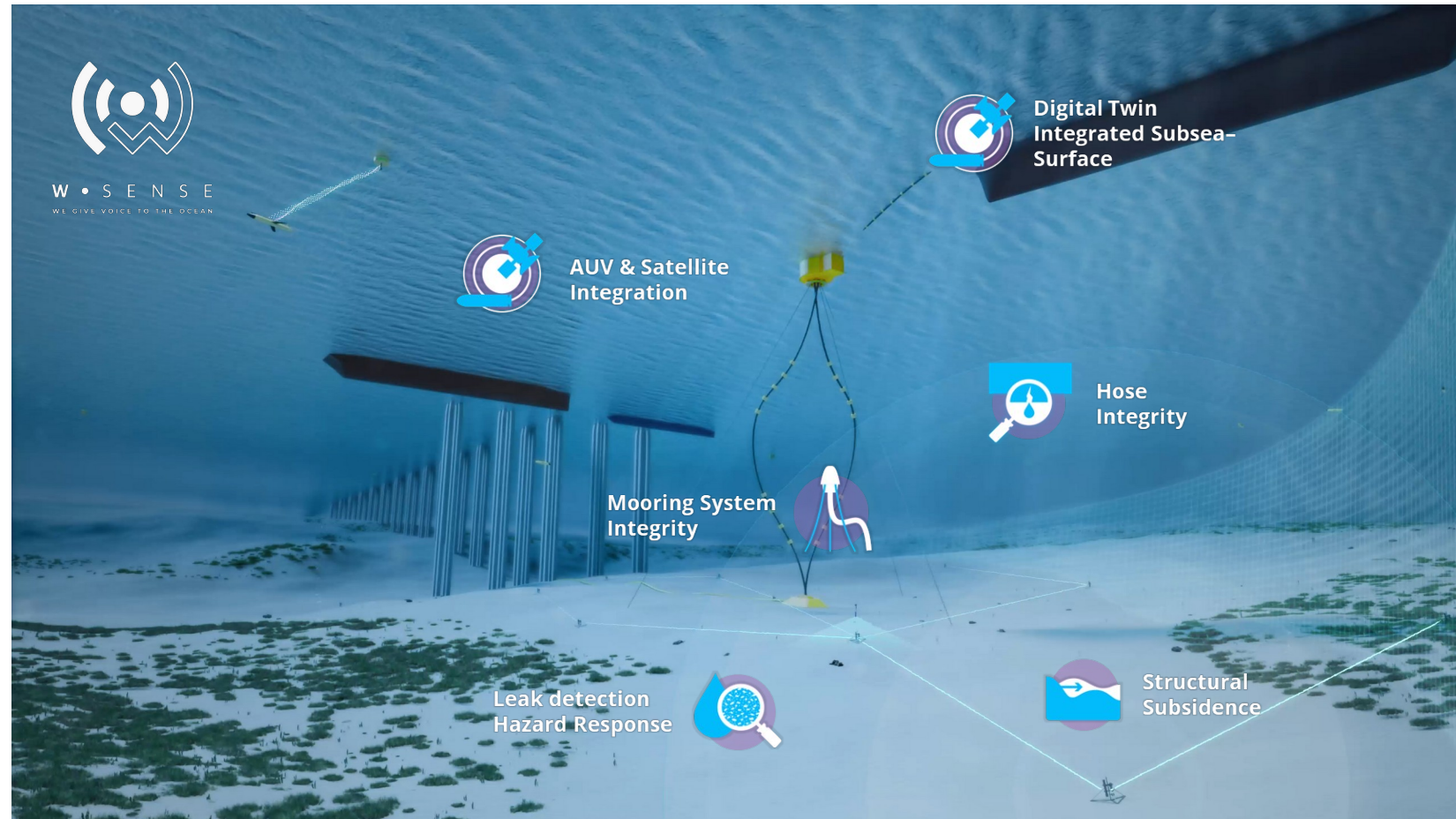
Deployment Architectures & Use Cases

- Temporary or permanent **seafloor networks**
- **Multi-hop nodes** + surface gateways (**satellite uplink**)
- Integration with **AUV/ROV inspection**
- **Reusable** across sites
- No need to **modify existing subsea assets**



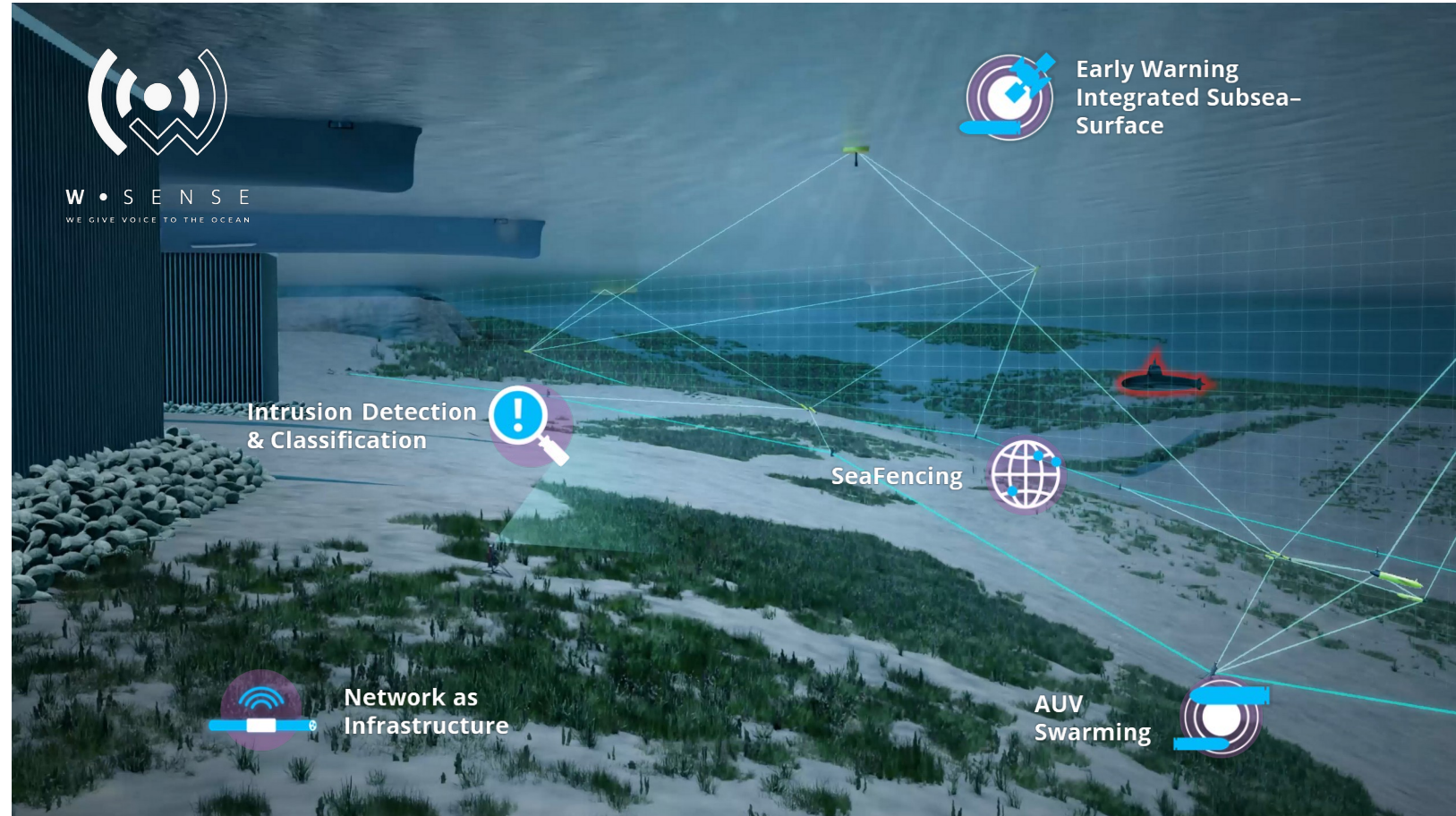
What Wireless Networks could Monitor

- CH₄ concentrations
- Dissolved gases and turbidity
- Pressure, temperature, vibrations
- Mechanical stress & seabed motion
- Early leak indication & anomaly detection



Security & Infrastructure Protection

- Real-time **seafencing** of critical assets
- Detection of **unauthorized vessels/ROVs/divers**
- No **cable vulnerabilities**
- **Dual-use:** environmental + security





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- Wireless networks are **field-validated with INGV**
- **Outperform cables** in resilience & flexibility
- Match future **regulatory needs for methane monitoring**
- Bridge scientific **geophysics with industrial applications**
- Could leverage **dual use applications**

Wireless multi-hop networking is becoming the standard for subsea monitoring