Detect and protect:

The pathway to atmosphere detection and control of the future

Presented By: Nathan Stevenson - Systems Architect

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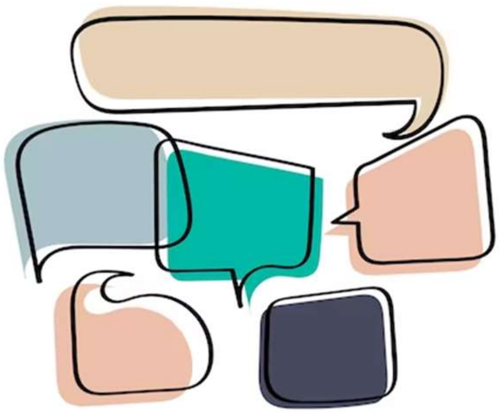
Nathan Stevenson

- BEng (Hons), IEG MIET - Electronics & Computer Engineering - Edinburgh Napier University (2013)
- Nathan joined Analox in 2014, progressing from Systems Engineer to System Architect in eight years.
- Leading the Systems team, he spearheaded major defense projects, including Analox's largest-ever contract.
- Recognized with Incorporated Engineer Status in 2022, Nathan's excellence earned him a nomination for IET's Engineer of the Year in 2023.

Themes

- Atmosphere monitoring requirements
- Designing for the needs of future submarines
- Atmosphere monitoring vs control



Submarines are changing

Advancements in technology and improved systems have propelled diesel boats to achieve extended underwater endurance, settling at a standard of 7-14 days. AIP boats showcase even greater progress, with 28 days becoming a prevalent underwater endurance period. Nuclear boats, originally deployed for 90 days, are now extending patrols to 120 days or more.

With prolonged submersion, contaminants accumulate in the breathable environment, emphasizing the need for proactive measures to safeguard the crew's well-being during extended underwater missions.

Image courtesy of BAE Systems

Legislation is changing

Submariners work in a continuous 24/7 environment, diverging from the standard 8-hour workdays seen in many workplaces. Additionally, Occupational Exposure Levels (OEL) for contaminants like NO_2/SO_2 are decreasing, with the UK Health & Safety Executive recommending a division by 5 for continuous exposure.

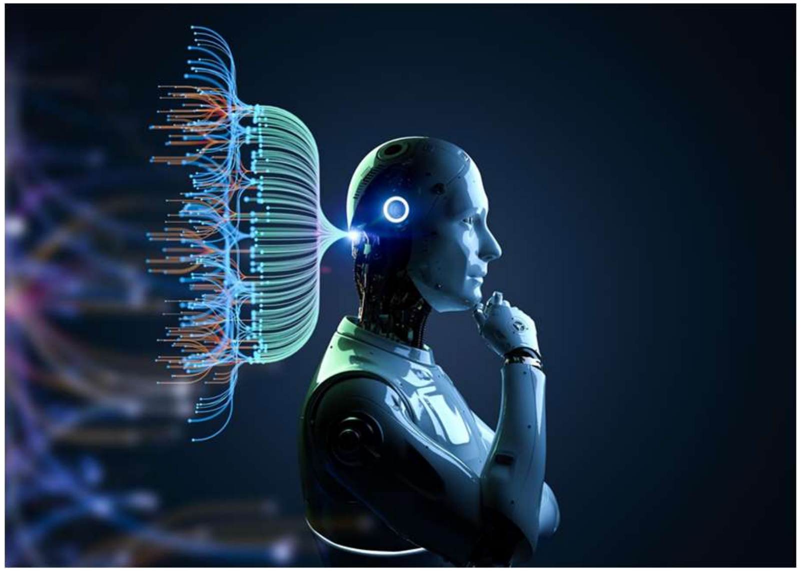
This shift underscores the urgent need to prioritize and ensure the safety of the submarine's breathable environment.

The world around us is changing

Many submarine nations find it very difficult to get crew. There will be less crew on future submarines.

As new generations of crew come on-board, they have different expectations, we have to appeal to the 'crew of the future':

- Intuitive user interfaces
- Seamless integration between systems
- Instrumented systems with in-built diagnostics
- Reduced need for hands-on maintenance



Cost of ownership is always an issue for Governments

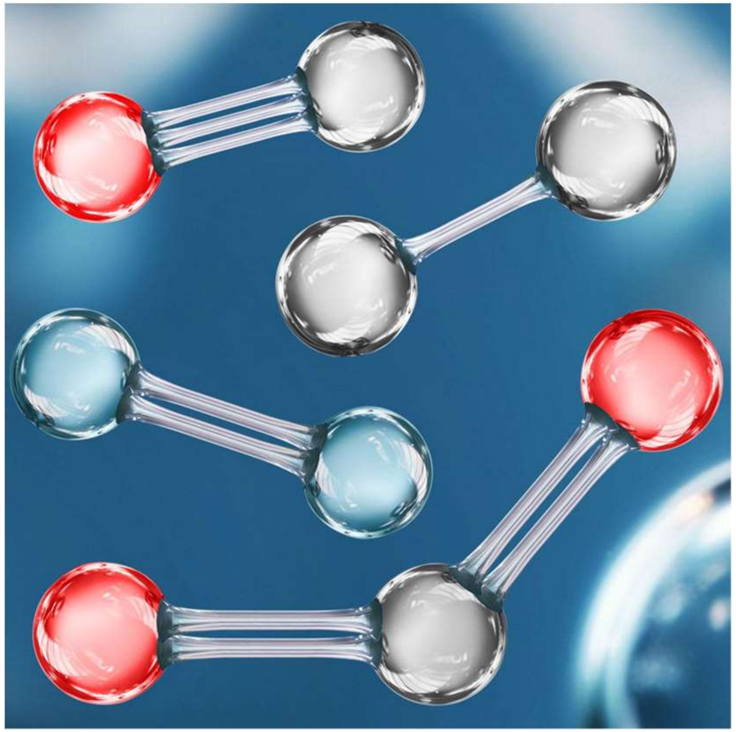
Governments are much more aware of the importance of data security

Environmental concerns mean that we cannot just dump everything overboard.

5 Key Gases

What must a submarine monitor

- **Oxygen**
  - Key life gas for the crew but can also be an explosion hazard if levels get to high
- **Carbon Dioxide**
  - Produced by the crew continuously and must be captured
- **Carbon Monoxide**
  - Produced by the engines and gas hobs for cooking
- **Hydrogen**
  - Produced as part of normal battery charging, can be an explosion hazard if not controlled
- **Refrigerant**
  - Leaks from fridges and cold water plant, at high levels can be a hazard to life



Challenges of measuring gases on a submarine

The submarine environment is an interesting place:

- It can be subject to rapid pressure changes when engines are running.
- It can be wet....it can be dry
- There are a large number of atmospheric contaminants, many of which interfere with each other.
- Treating atmospheric contamination.........creates more, but different, and often unexpected contamination!
- The Occupational Exposure Levels are lower than on Civvy Street, so the gas sensing technology is really stretched to meet the low detection levels.

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Distributed vs centralised atmosphere monitoring systems

In general:

- Nuclear boats have centralised systems.
  - The gas list is too long for individual gas sensors and it would be too expensive to have distributed multi-gas analysers such as FTIR in every compartment
- Diesel / AIP boats have distributed systems
- The most advanced AIP boats tend to be hybrid - they have a distributed system for all life gases and an FTIR based system for fire gases and hydrocarbon contaminants

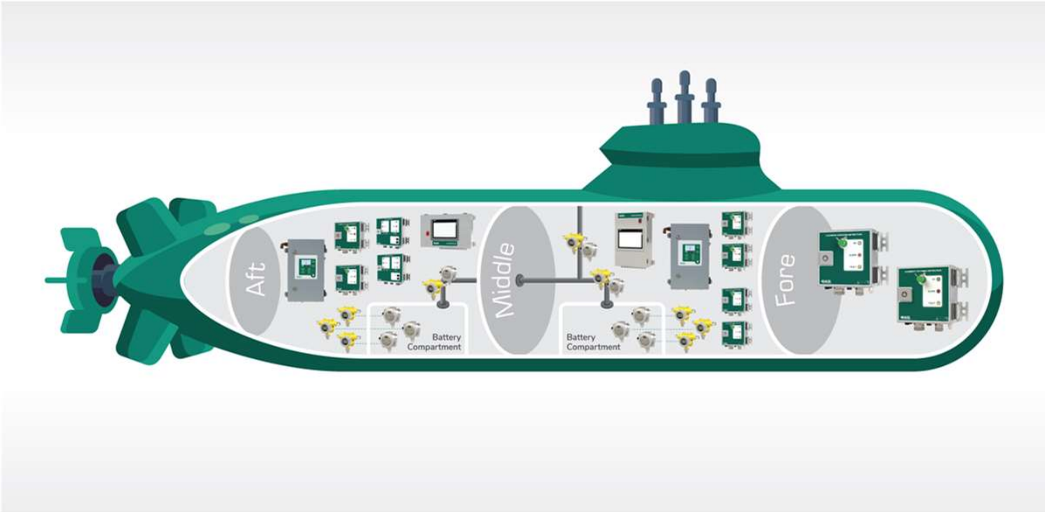
DAMS (Distributed Atmosphere Monitoring System)

- Flexibility & Robust Design: Adapts seamlessly to diverse operational needs.
- Centralized Monitoring via PLC: Sensors monitored centrally for real-time analysis.
- Local Sensing & Crew Alerts: Issues alerts in aft, middle, and fore sections.
- Partial Pressure Sensing: Ensures accurate readings amid pressure fluctuations.
- Detectable Gases: Detects O2, CO2, CO, H2, and refrigerants.
- Full Through Life Support: Ensures ongoing reliability throughout the submarine's life.

Gas detection in the areas it is required

When an atmosphere event occurs then monitoring in specific locations reduces the hazard to the whole crew, examples are

- CO monitoring around the diesel engines
- Refrigerant monitoring around water chiller plants
- Hydrogen monitoring in the battery compartments



Typical Centralised System

The Atmosphere Analyser (AA)

- The Atmosphere Analyser (AA) is a multi-gas analyser designed for submarine use. It has the capability to measure up to 30 gases continuously to ensure crew safety.
- The AA has the capability to sample gases from up to 16 compartments via sample lines.
- For larger submarines, a number of AAs can be connected together to provide measurements from a greater number of compartments and also to provide redundancy.

Laboratory in a box

For long endurance boats the monitoring of trace gases requires laboratory grade instruments. The required limits of detection (LOD) are far too low for industrial equipment. We have to de-risk the use of these technologies in a submarine environment.

Unfortunately, these instruments were not designed to meet military EMC / Shock / Environmental requirements.

Our solution is to create a laboratory in a box:

- Fixed operating temperature
- EMC shielded
- Built in shock protection
- Controlled humidity

This approach allows us to incorporate new laboratory grade techniques into the equipment over time, to keep limits of detection as low as possible, as legislation changes

A SIL2 rated Oxygen sensor is also included in the system

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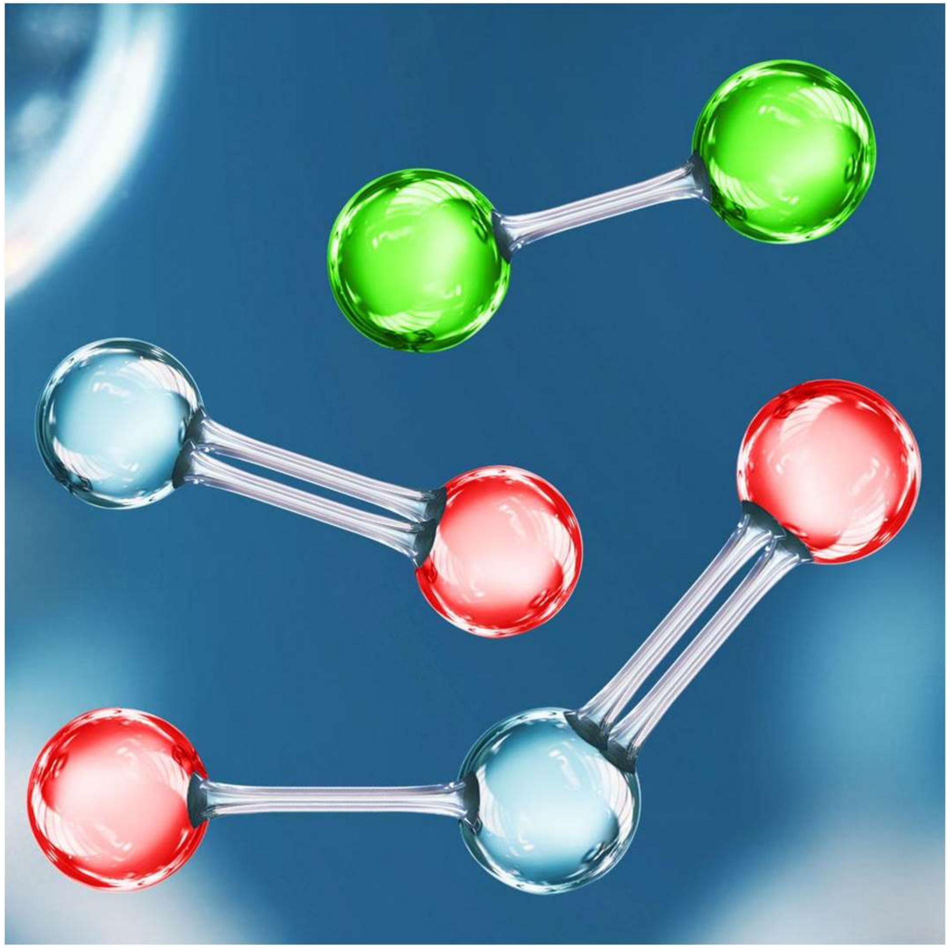
Standalone detectors for unique scenarios

- There may be scenarios where a full DAMS system is not feasible for the submarine. In these situations the DAMS sensors can be installed as a standalone detector only requiring a 24V DC supply.
- These detectors act in the same way as an integrated detector and can be integrated into a DAMS system at a later date
- The standalone detectors can also be offered as a direct replacement for existing industrial detectors. In this configuration, they replicate the signals, eliminating the necessity to update the platform management system.

Future Gases to Monitor

Analox has actively collaborated with multiple nations to identify crucial gases that require monitoring onboard submarines. They assert that NO (nitric oxide) and NO2 (nitrogen dioxide) are useful indicator gases post-fire, providing insights into the levels of other hazardous gases in the air.

Chlorine has emerged as a growing concern for numerous nations, primarily due to the prevalent use of plastic industrial equipment onboard submarines. In the event of a fire, these materials can release chlorine gas to potentially harmful levels if the submarine cannot be safely vented. Monitoring chlorine levels becomes imperative in ensuring the safety and well-being of submarine crews.



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NO and NO2 measurement

- Analox has developed a dedicated monitor for NO and NO2 based on our SUB MkIIIP platform
- This detector is designed to be a fixed monitor for continuous monitoring on board
- Post incident the SUB NOX can be taken to the incident location allowing local monitoring via the built in batteries and pump
- The unit will automatically switch to it's internal batteries on loss of power

Future gas sensing technologies on-board

- Laser Absorption Spectroscopy (LAS) - so far this has not fulfilled expectations on long endurance boats. Long term stability is difficult to achieve
- Chemiluminescence - largely the preserve of laboratory analysers. Good for NO_2 / NO / SO_2
- FTIR using broadband laser source - modifying existing FTIR technology to provide a more intense emission leading to higher accuracy and better discrimination between contaminants
- Photonic integrated circuit - IR gas sensing
  - IR light directed by a wave guide
  - Increases IR absorption path length on a much smaller platform
  - Good for all IR detectable gases e.g CO, CO_2 and refrigerants

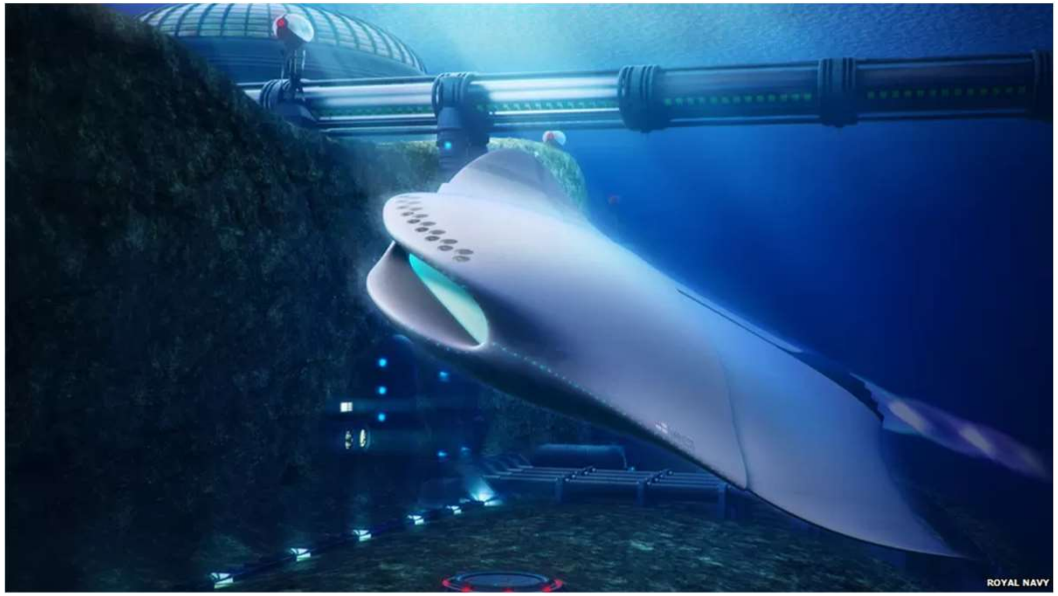


Image courtesy of Royal Navy

UV-Vis Spectroscopy

- UV-Vis Spectroscopy - this is the UV equivalent of FTIR. Very flexible, high performance, laboratory analysers.
- Standard analysers use arc discharge lamps which are very fragile to shock and vibration
- UV LEDs can be targeted at specific gas in much smaller package allowing for multiple gases to measured in same space envelope

Technology Highlight - FTIR

Analox have an exclusive relationship with Gasmet Technologies for the use of their FTIRs on submarines.

For the very best performance, a fixed rack mounted FTIR, in a temperature controlled environment can give great results. This is what we do in the Analox Atmosphere Analyser.

Latest generation portable FTIR has the performance to measure most of the trace gases on a submarine, but it does not meet the shock / EMC / Tempest (are there more) requirements, but Analox can adapt it to be compliant and simple to use. O_2 measurement also included.

A single unit could measure *80% of the trace gases required on long endurance submarines

Image courtesy of Gasmet Technologies

* not Cl_2, F_2, Br_2, N_2, H_2

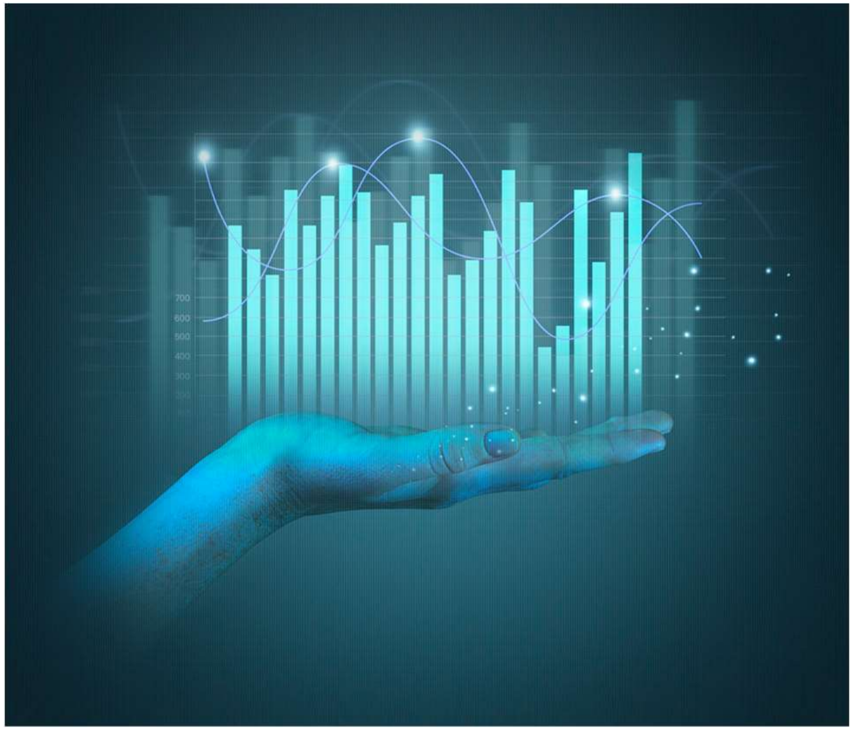
Critical decision making equipment

- The detectors can be directly integrated into either the platform management system or specific processes on the submarine through Volt Free Contact (VFC).
- Alternatively the VFC can be used to drive a beacon for local alarm indication to the crew in locations where the detectors can not be seen.

Information for the moment and for later

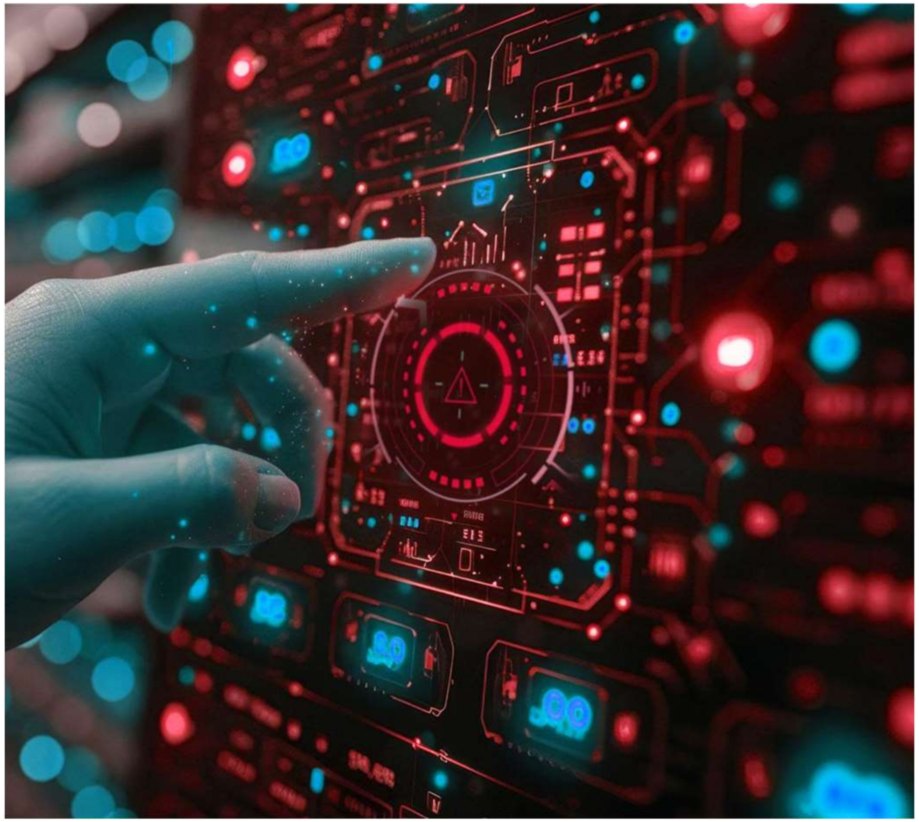
Advantage of using a networked DAMS

- All gas readings are updated to a central PLC and PMS every 10 seconds ensuring all of the critical information is available when it is needed.
- Utilizing centralized data logging within the PLC cabinet facilitates a streamlined export of gas readings for a specific patrol.
- This streamlined approach enables post-patrol analysis of gas readings, aiding in the detection of trends onboard during the patrol, and allowing for cross-analysis with any onboard events.
- To ensure data security, the information is safeguarded within the PLC cabinet using high-security locks that adhere to industry standards.



Monitoring for fault states

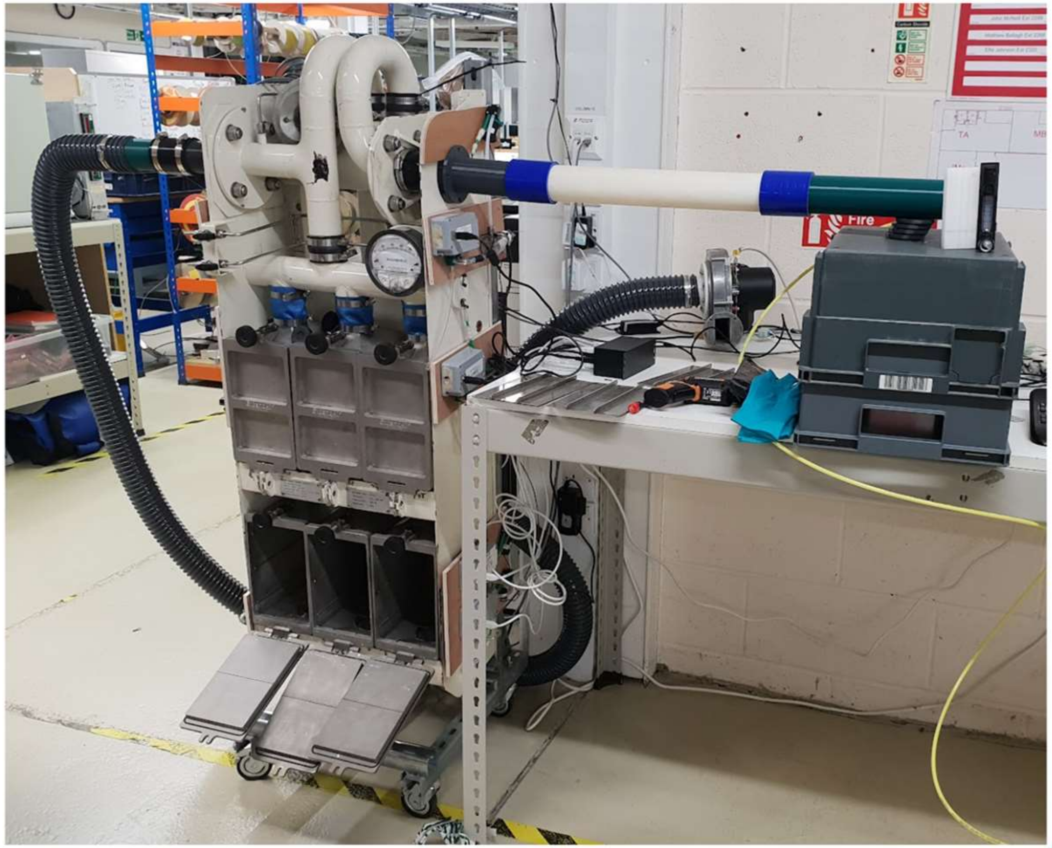
- Analox has worked with a number of customers to use atmosphere monitoring to help detect faults and maintenance tasks for other key pieces of equipment.
- An example of this is monitoring the CO_2 level in the BIBS system to the PPM level to determine if the filters are depleted.



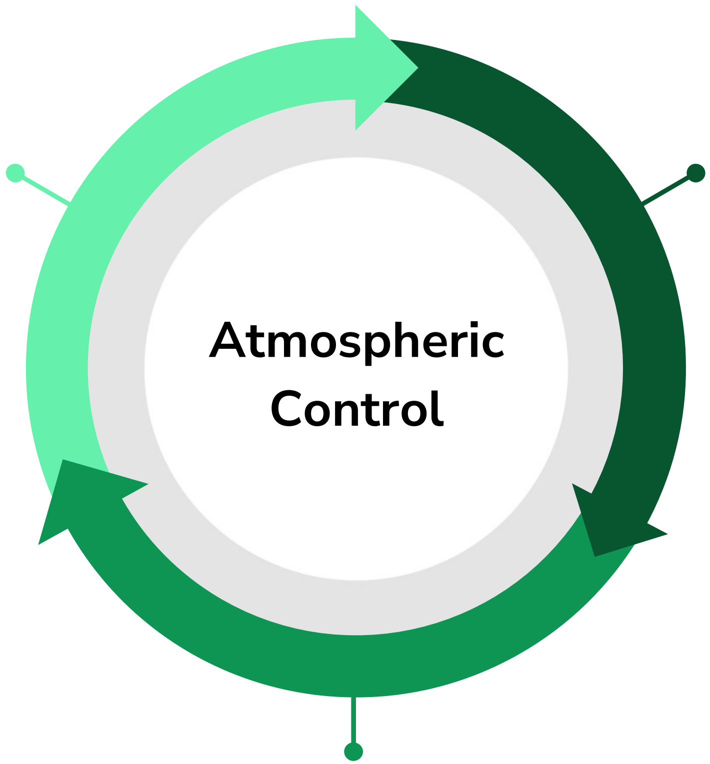
Systems Integration & Automation

Holistic approach to Atmosphere Control:

- If CO2 is high we can enable more scrubbing
  - On diesel boats we can improve scrubbing efficiency by 20%, by actively measuring scrubber performance.
  - Analox have conducted trials on automating the Dutch Walrus class scrubbers
- Active control of life support gases requires functionally safe systems. Failure of the systems is a threat to health / life.
- Calibration & maintenance reminders and guidance

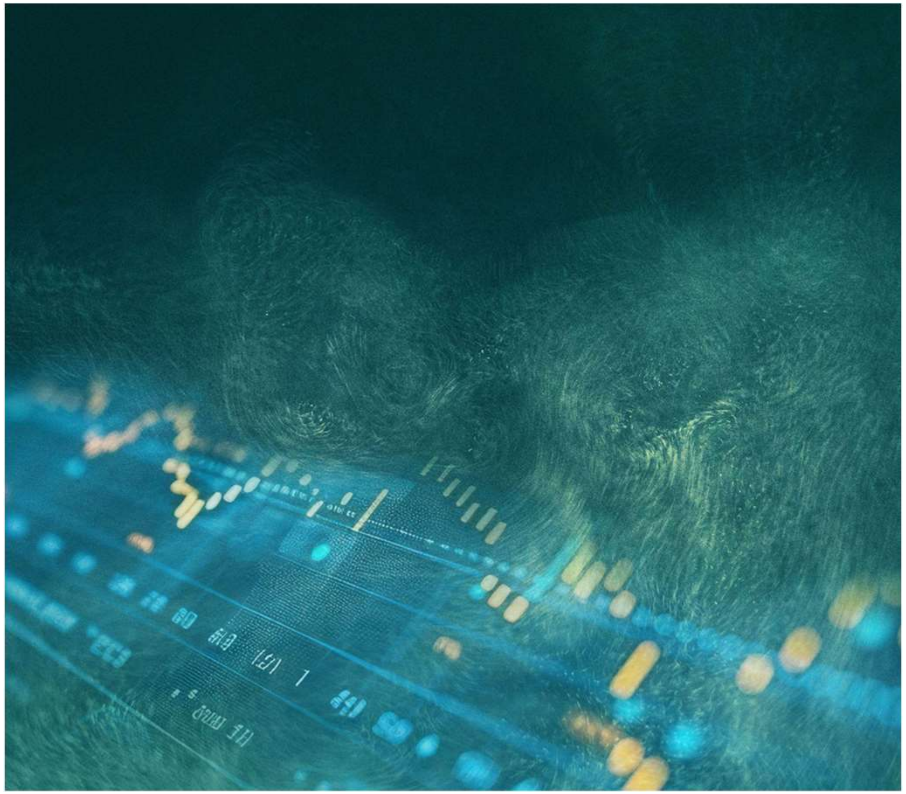


The Automated Atmosphere Cycle



Atmospheric Control Examples

- Controlling oxygen generation based on live oxygen readings from around the submarine
- Increased Carbon Dioxide scrubbing when high CO2 detected on board
- Monitoring the HVAC system to detects blocked or depleted filters to allow proactive maintenance
- Monitoring compartment temperature and humidity to better control HVAC output



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