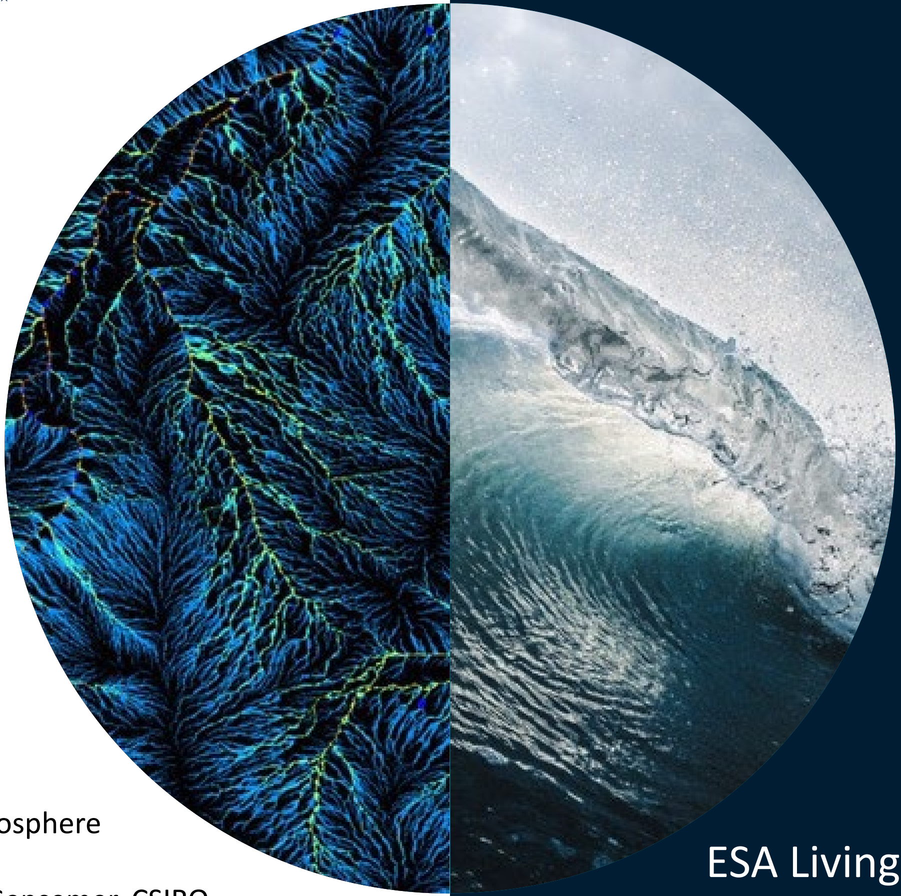
Challenges to implementation of extensive in situ sensor networks in support of aquatic ecosystem focused satellite missions



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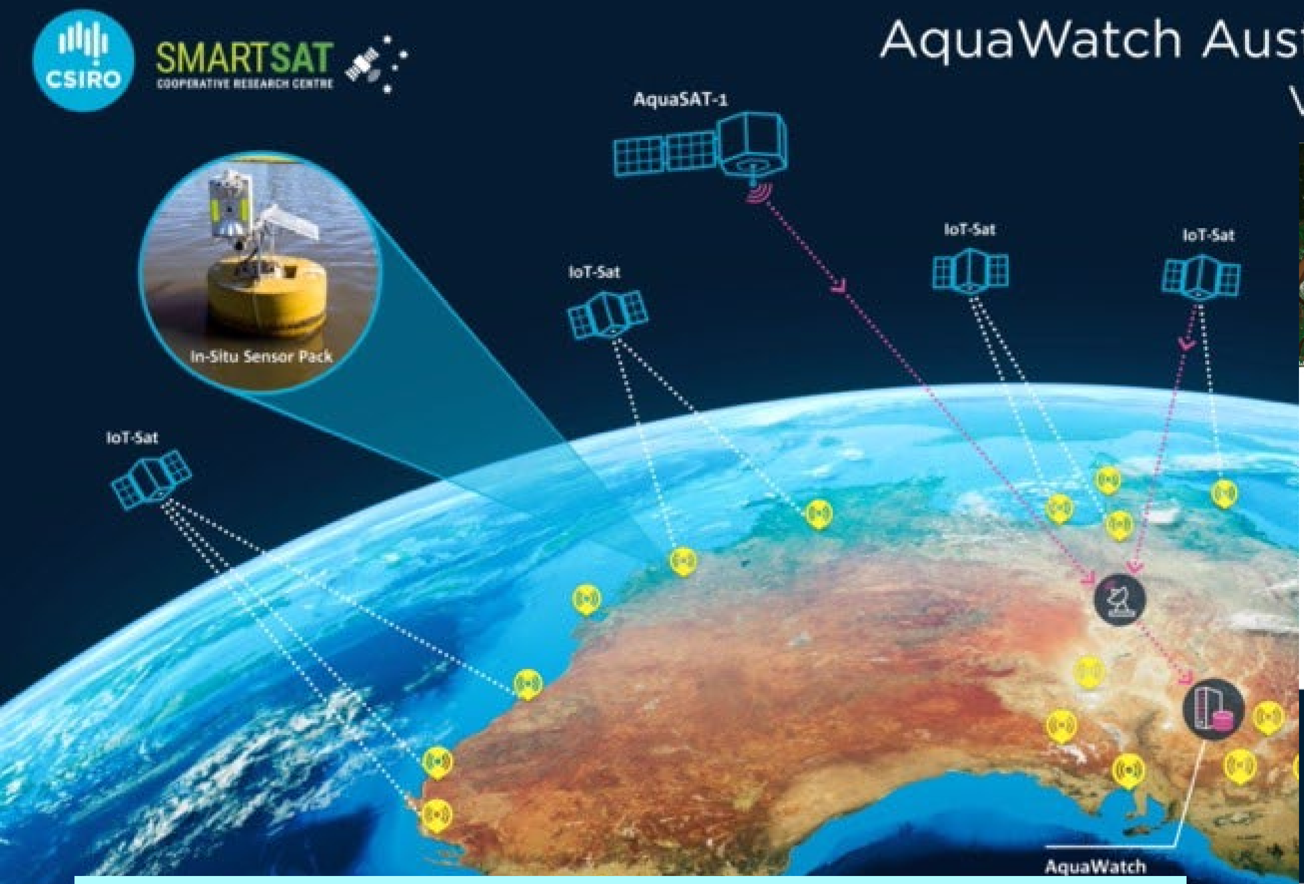
ESA Living Planet Symposium – 26 May 2022

AquaWatch Australia Mission Concept

Virtual Satellite Constellation



2022–23 Budget: $1.16 billion for the first phase of a National Space Mission for Earth Observation (NSMEO)

CSIRO

SMARTSAT

AquaWatch Australia

An integrated aquatic observing system with global applications

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Why AquaWatch Australia?

Healthy aquatic ecosystems support a rich and varied community of organisms providing resources for human health, environmental, agricultural or industrial applications. E.g., the availability and quality of freshwater continues to deteriorate across Australia due to a range of stressors and seagrass, kelp and coral reef systems are under threat. There is currently no national integrated system providing holistic aquatic ecosystem information. AquaWatch Australia will solve this scarcity of information in a manner that is transferable to other nations.

An ambitious national mission

This Mission is a partnership between government, industry and research to boost Australia's capability in Earth Observation (EO) and aquatic environmental monitoring and management. The aim of AquaWatch is to:

- Design an integrated system that combines data from existing EO satellites, with a dense network of purpose built *in-situ* aquatic sensors enabled by an Internet of Things (IoT) connectivity.
- Explore opportunities to design and develop new sensors and launch and operate bespoke dedicated EO hyperspectral satellites optimised for monitoring aquatic ecosystems globally.
- Produce an observation and information system, integrated within a data integration and prediction framework.

AquaWatch Australia system: Reliable – Timely – Systematic

AquaWatch will monitor and predict inland, coastal and coral reef water quality and ecosystem health in Australia, applicable across the globe.

This continental scale EO system will provide managers, industry and policy-makers with timely data to inform, predict, monitor and improve management of inland, coastal and coral ecosystems.

To meet our goals ongoing work has so far included: (See references)

- **End-user consultation** studies, which have catalogued end-user needs and **Satellite design concept studies**, to analyse the trade-offs between aquatic ecosystem monitoring user needs and the space engineering & operational capabilities. These allow cost estimations to inform the business case.
- Concepts for a cost-effective **in-situ sensor network** providing both services for satellite calibration and product validation as well as to extend the range of in situ parameters measured necessary for forecasting and prediction systems.
- Development of an **end-to-end simulator**, to understand the effects of instrumental and environmental parameters to optimise satellite sensor design.
- **Pathfinder imaging spectrometer sensor concepts, data analytics research** and **national and international pilot studies**, to further road test AquaWatch design concepts and enhance end user engagement.
- **National & International Science Advisory Groups**

WATER QUALITY ISSUES	PARAMETERS TO MEASURE
Eutrophication & sediment loads	Apparent optical properties (AOPs), Inherent optical properties (IOPs), pigments, biomass, CDOM, suspended matter
Algal blooms, including cyanobacteria	AOPs, IOPs, algal pigments, phytoplankton functional types
Black water events	AOPs, IOPs, CDOM and DOM, light attenuation, oxygen, salinity
Coastal & coral habitats	Same as above + shallow water bathymetry & benthic variables
Contamination	Conductivity, pH, salinity, heavy metals, organic micropollutants, microbiology, eDNA, hydrocarbons, toxins

Table 1: Examples of aquatic ecosystem issues that AquaWatch will address (AOPs include hyperspectral reflectance & light attenuation; IOPs include spectral absorption and (back) scattering properties).

By developing Australia's industry capability, the Mission aims to complement existing relevant hyper - and multispectral EO missions, contributing to a virtual constellation for aquatic ecosystem health.

Global interest in such an integrated system for aquatic ecosystem trends, early warning, and predictive modelling, aligns directly with information needs for reporting on SDG's, SEEA and many levels of State of the Environment reporting as well as informing aquatic ecosystem management and utilisation strategies.

AquaWatch Australia will lead to improved aquatic ecosystem monitoring, management, and early warning.

Safeguard drinking water · Protect aquatic ecosystem resilience · Cultural values · Land use & development planning · Early warning of harmful algal blooms · Improve water management · Industry, policy & governance · Environmental impacts

AquaWatch Australia Mission Concept

Virtual Satellite Constellation

See poster 314 on the AquaWatch Mission today!

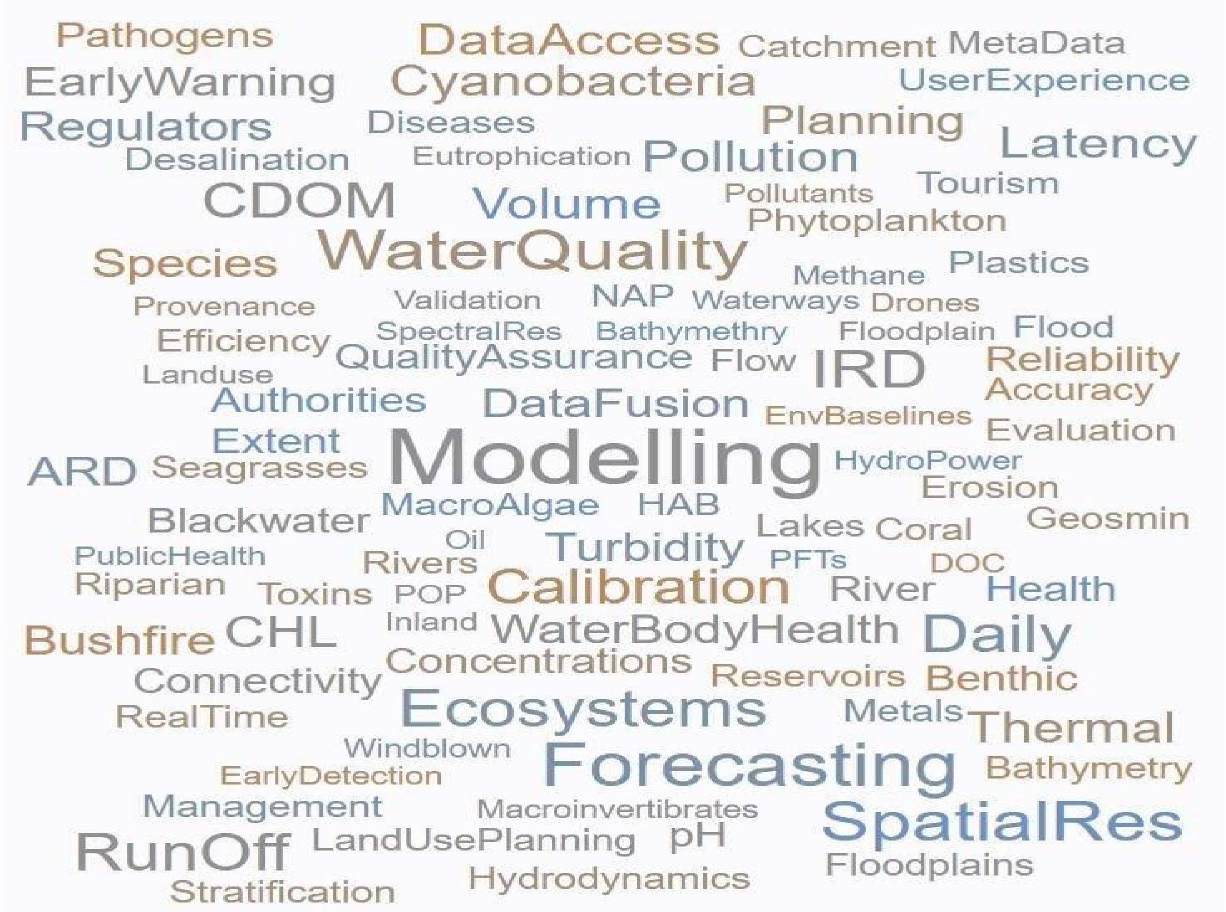
An in-situ sensor network

Addresses three purposes:

- Satellite measured signal vicarious calibration (water surface radiances and reflectances)
- Satellite water quality product validation (IOP’s & optically active constituents=>SIOP’s)
- Extending parameters for forecasting and prediction (optical and non-optical constituents)

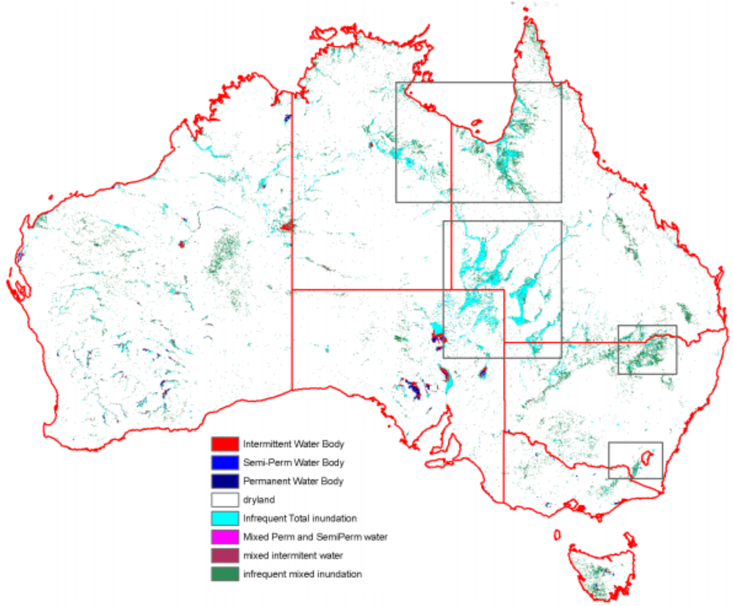
https://smartsatcrc.com/publications/technical-reports/

An extensive survey of Australian end users:



The challenge

- How do you cost effectively roll out an in situ sensor network at the scale of a continent with very remote areas from tropics to temperate ecosystems?



The challenge of *in situ* monitoring

- Declining surface networks
- Poor data coverage
- Poor temporal continuity
- Inconsistent sampling
- Variation in data accessibility
- Limited understanding of the implications of extreme events on water quality

Core characteristics

- Cost-effective
- Easy to maintain
- Robust
- Timely
- Credible
- Open
- Representative

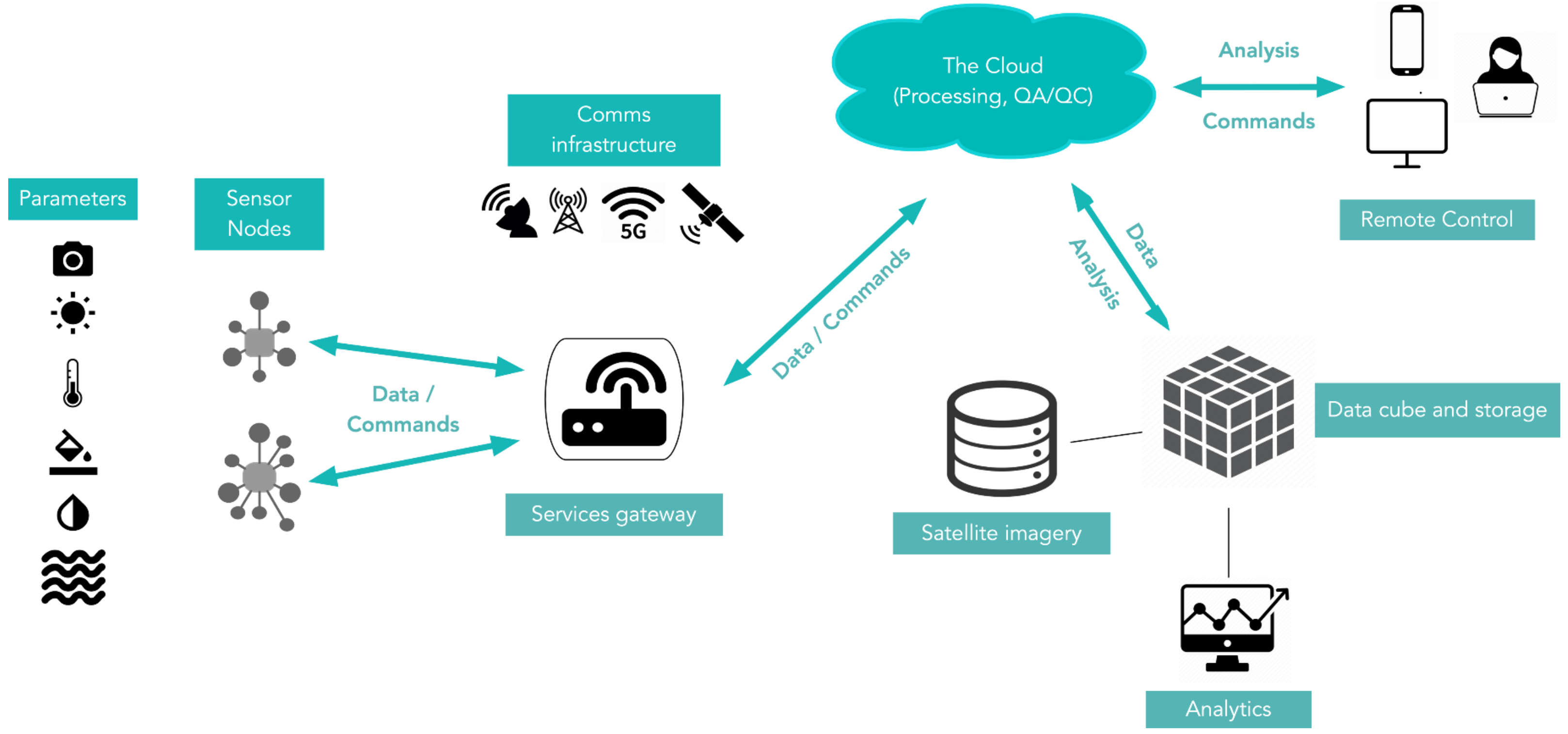
Problems to be solved

Robustness	Reliability and maintainability	Availability	Interoperability and flexibility	Unit cost (manufacture and deployment)
Integration	Scalability	QA/QC	Standards and protocols	Security
	Development of robust AI/ML approaches	Where located?		

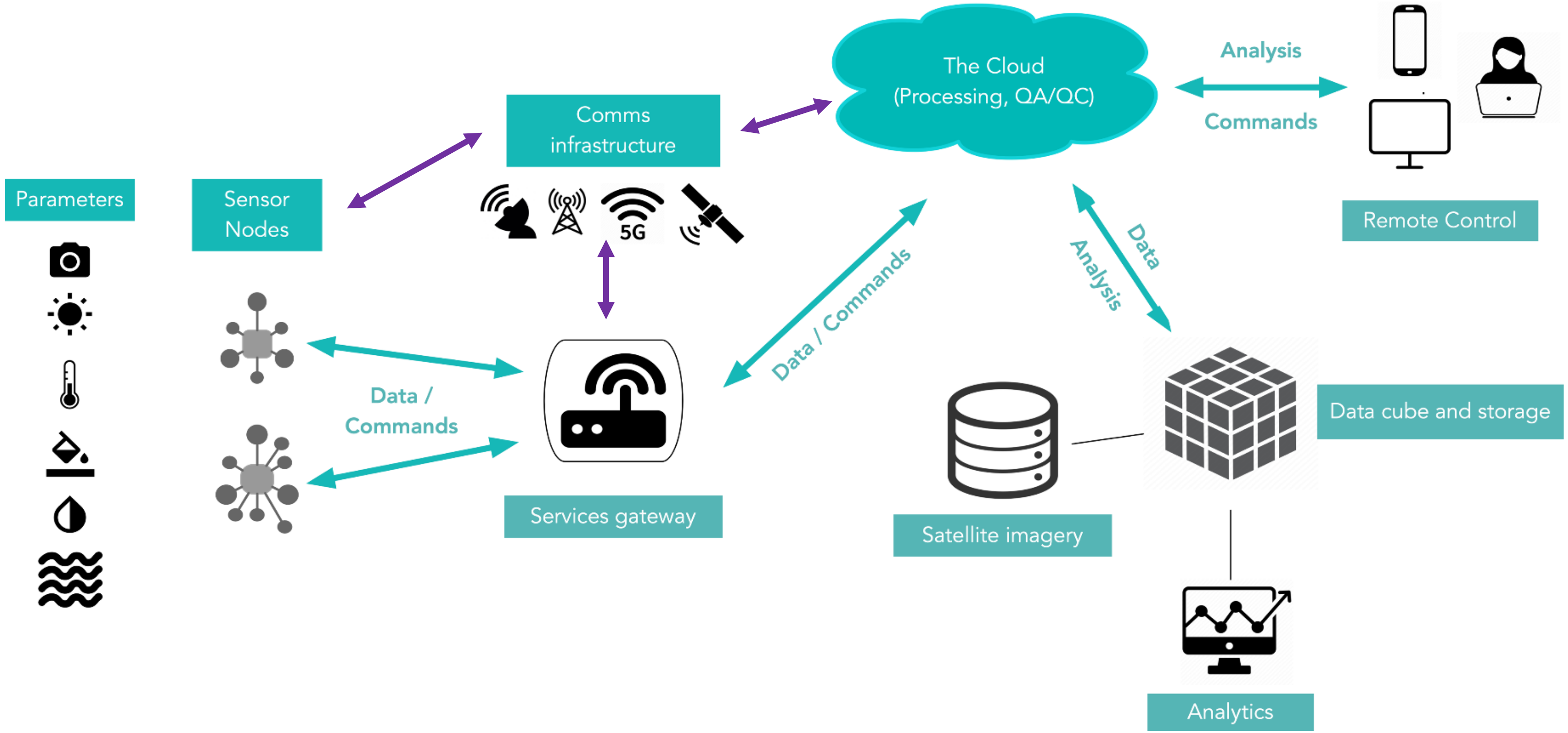
Hardest to solve: Robustness; Reliability and maintainability; Availability; Interoperability and flexibility; Unit cost (manufacture and deployment)

Solvable: Integration; Scalability; QA/QC; Standards and protocols; Security; Development of robust AI/ML approaches; Where located?

Internet of Things the solution?



Internet of Things the solution?



IoT Low-cost Sensor TRL levels
Stand Alone – Remote Area

TRL Levels		Parameters	Technologies
Commercial / Operational	**TRL 9**	Conductivity, pH, Salinity, Temperature	Thermocouple, Imaging, Electrode
Pre-production	**TRL 8**	eDNA, DO, Forel-Ule, Reflectance, Pigments	Fluorometry
Field test	**TRL 7**	Turbidity, Attenuation, Transparency, TSS	Optical spectrometry, Lab on a chip
Prototype	**TRL 6**	CDOM	Reagent based, eco qPCR
Bench / Lab testing	**TRL 5**	Cell counts / ID, Nitrate	In situ analysers, Microfluidics
Detailed design	**TRL 4**	Toxins, Oil	Chromatography, Light scattering
Preliminary design	**TRL 3**	Heavy metals, Microbiology	GC-MS
Conceptual design	**TRL 2**	Organics, Phosphate	
Basic concept	**TRL 1**	Pesticides / Herbicides	

The path forward

- Rolling out IoT water quality networks will be a challenge.
- A lot of expert work required (low TRL) to realise a scalable solution (high TRL)
- Sensors → Sensor Networks
- What we develop/design could be relevant for other countries in the 40 N via the equator to 40 S latitudes with sparse infrastructure and large land and coastal areas.
- We are interested in collaborating (e.g. are our TRL level assumptions correct?)

Let's collaborate and exchange expertise (at poster 314)

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