Clear Shores: Enhancing Water Quality Monitoring

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Mission

Mission goal:

"Improve monitoring of the quality of water in and around Aotearoa New Zealand for researchers, decision makers and the public at large through innovative space technology"

- *Miniaturised spacecraft*
- *Novel deployable imaging technologies*
- *Responsive mission operations*
- *Tasking optimization through on-board cloud detection*
- *End to end programme from user engagement to data dissemination*
- *Currently pending funding decision for 2023 kick-off*
- *A first full science-driven mission for Aotearoa New Zealand*
- *Launch targeted for 2027*

Project partners

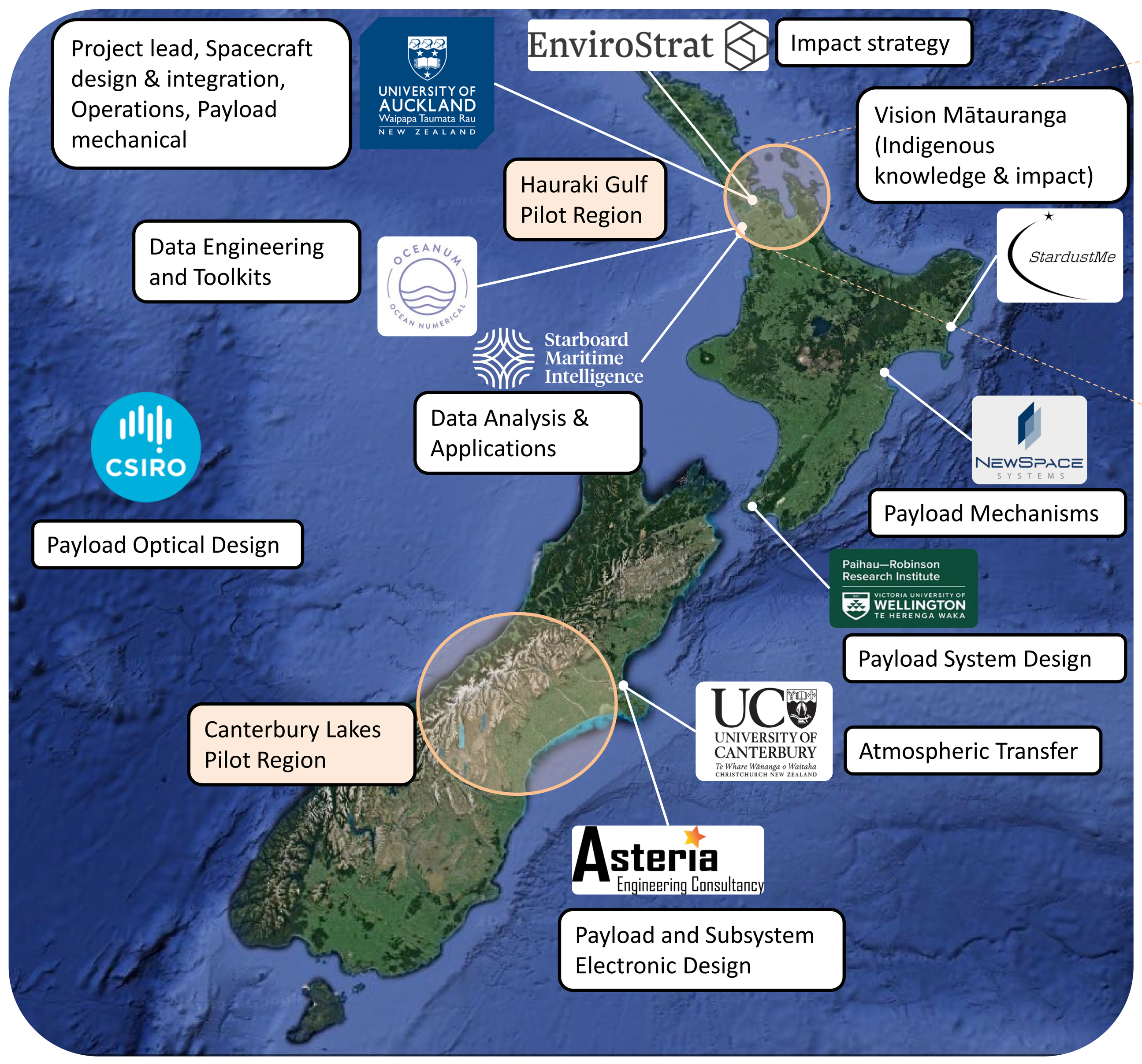


Figure 1.: Programme partners throughout Aotearoa New Zealand with pilot regions highlighted in pink

The Clear Shores programme is intended to be a truly national mission, bringing together expertise in environmental sciences, upstream spacecraft and instrumentation engineering, through to downstream data handling and impact strategies, including incorporation of Mātauranga Māori, the indigenous knowledge of Māori.

Motivation

Figure 2.: Coastal water imaged by LandSat-7/ETM in March 2002. Note, however, that the spatial resolution of the image is 30m at best and the satellite revisit time is 16 days. Consequently, acute, dynamic events are poorly monitored and will have only limited value to decision makers.

There are 3,820 lakes in New Zealand that have a surface area larger than one hectare. These are considered taonga (treasured possession) by tangata whenua (people of the land, Aotearoa's indigenous Māori population). Water quality is monitored in less than 10% of these.

Currently there are no satellite sensors optimised for lake, estuarine and coastal water quality monitoring in New Zealand. Consultation with representatives of New Zealand's aquaculture industry, environment agencies, and NGOs have highlighted limitations around low spatial resolution provided by the existing oceanographic missions, and sensors that do have high resolution mapping are not optimised for water quality. Inland and coastal water monitoring is therefore heavily reliant on resource intensive and fragmented in-situ sampling, which in turn presents challenges to predictive modelling

Payload

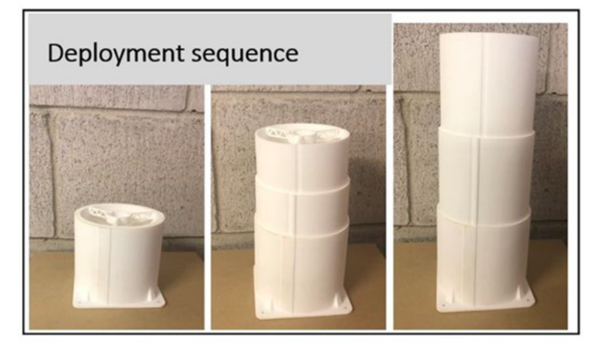
Sensor overview

- 10m ground resolution requires very fast sampling. Initial concept uses a TDI (time domain integration) filter radiometer operated in a push-broom mode.
- An off the shelf CCD sensor with mosaic filter arrangement supported by a dedicated high-speed link and data recorder/ processor.

Optical configuration

- Payload to make use of deployable barrel and alignment technology under development at Te Pūnaha Ātea – Space Institute providing a ~20cm aperture and ~50cm focal length in a catadioptric telescope.

Parameter	Minimum	Target
Ground Resolution	30m	10m
Signal to Noise Ratio (SNR)	100:1	200:1
Channel Bandwidth	20nm	10nm
Dynamic Range	10bit	12bit
Image width (swath)	8km	20km
Image strip length	20km	80km



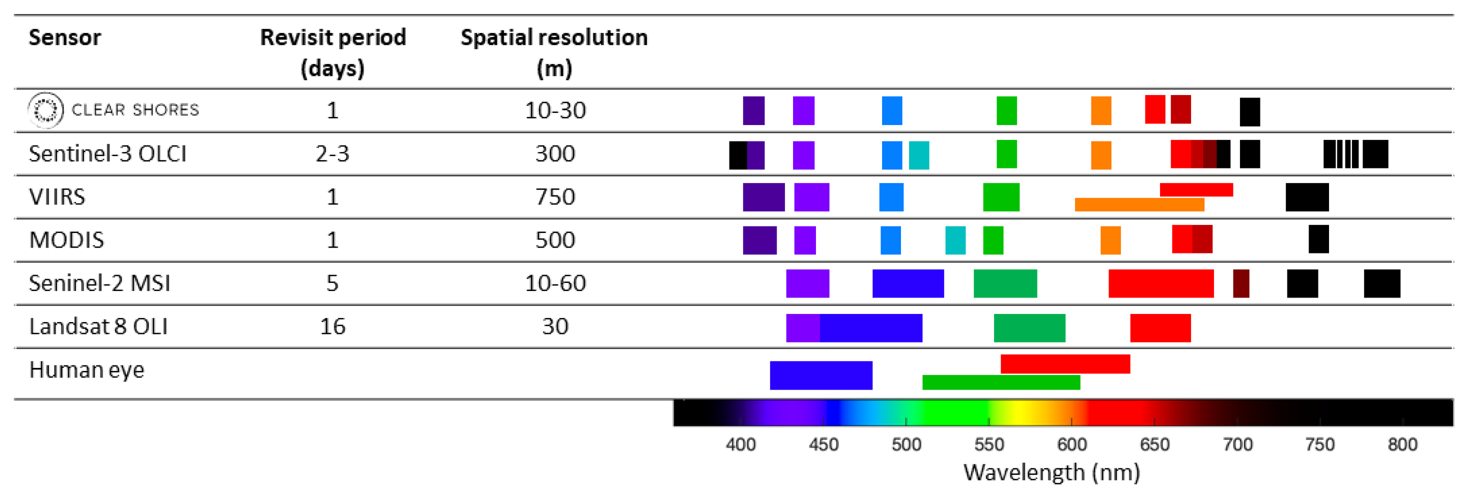


Figure 3.: Spectral bands, revisit, and spatial resolution of the proposed CS-1 sensor to fill gaps in existing capabilities (bottom); target and minimum parameters for the CS-1 payload (top left); deployable optical system development models (top right)

Spacecraft

NanoSat pathfinder

- Rather than attempting to perform large scale image capture, Clear Shores aims to perform precisely targeted imagery, such that the spacecraft resources and sizing can be significantly smaller than most existing platforms.
- The proposed pilot mission is based on a 12U CubeSat form factor incorporating a novel deployable Optical Front End (OFE) to provide a long focal length within a small launch volume.

National capability

- Whilst the spacecraft is planned to largely be integrated at Te Pūnaha Ātea – Space Institute from existing COTS subsystems on the international market, the mission will showcase domestic capabilities from industry suppliers, particularly in Attitude Determination and Control (ADAC) and orbit maintenance. The larger moment of inertia than standard for this class of spacecraft and requirement for rapid and stable slew maneuvers make for a demanding control challenge.

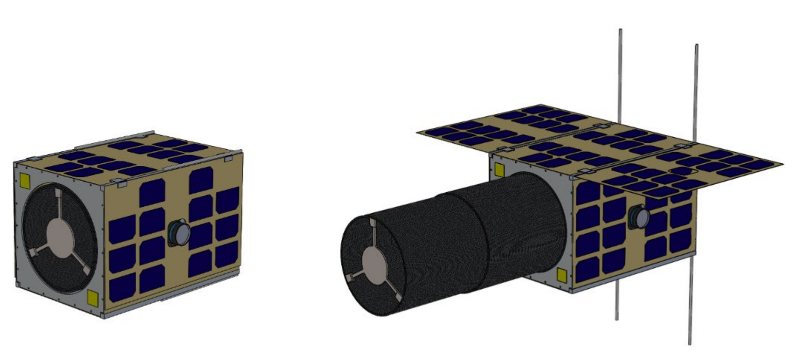


Figure 4.: Proposed satellite in stowed (left) and deployed (right) states.

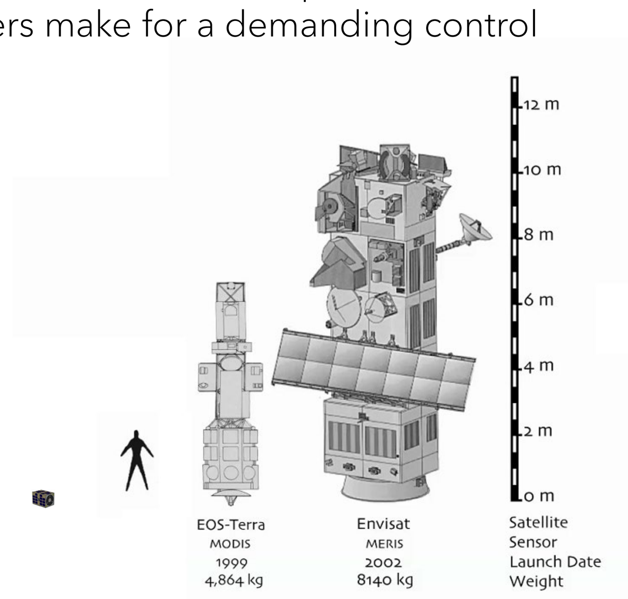


Figure 5.: Scale comparison of proposed satellite (left) to existing Terra and Envisat platforms (right)

Operations

End-user operation tasking

- Operationally the mission is focused on responsiveness to end-user needs. We are developing an online tool allowing stakeholders to make imaging requests, prioritisation and uploaded the spacecraft.
- Initial emphasis on two pilot regions for cross calibration with in-situ sensors and other imaging satellite target sites.

Cloud detection and avoidance

- The spacecraft will utilise an onboard camera and processing to assess cloud cover in target areas to autonomously prioritise imaging tasking, slewing between pre-selected targets dependent on the view from a look-ahead camera

Daily imaging

- Proposed for a 567km sun-synchronous orbit, the satellite incorporates a slewing capability allowing for 1-2 imaging opportunities at high priority targets per day, with ample opportunity for data downlink to deliver data back to users.
- It is anticipated the spacecraft will capture imagery on the daytime passes over New Zealand, with data processing and compression occurring before nighttime passes over the country. Additional downlink capacity would allow imaging to be performed in other target areas around the world.

Figure 6: Te Pūnaha Ātea – Space Institute Mission Operations Control Centre to be used for mission operations

Data Analysis and Dissemination

- Ground-truthing of Clear Shores data throughout the programme by hyperspectral reflectance measurements with in-situ radiometers; a partnership with the Australian AquaWatch mission will enhance cal/val activites.
- Atmospheric correction will be developed at the University of Canterbury. Science data products (e.g.: water quality attributes such as chlorophyll *a* concentration) will be validated by in-situ measurements by local researchers.
- A key element of the programme is ensuring data are made available in an appropriate way to stakeholders. Several wānanga (workshops) will be held to collaboratively develop and test tools and to support Māori innovation and enterprise in the space sector.
- Oceanum.io's Environmental Data Platform will be used as a basis for dissemination providing API access for application creation bespoke to users needs.
- To ensure a smooth introduction of Clear Shores data and add further value to the programme, the data dissemination platform will be established early on using existing data sets to build tools and integrate with existing programmes.

Constellation

- The deployable optical systems coupled with a standardized form factor are intended to enable the development of a scalable constellation of water quality monitoring satellites.
- With a target of national daily revisit coverage of all critical areas achieved with a constellation, capacity would be available to be rolled out globally.
- Additional data relay via IoT would be supported by the constellation to allow for regular data collection and integration of in-situ sensors.
- The Clear Shores is a pathfinder programme that includes a dedicated work package to perform constellation design and develop the business case for a commercially driven constellation making use of the generated IP.

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Follow the Mission at **www.clearshores.org**