Taiaho Observatory

An Automated Future Optical Communications Ground Station

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Abstract

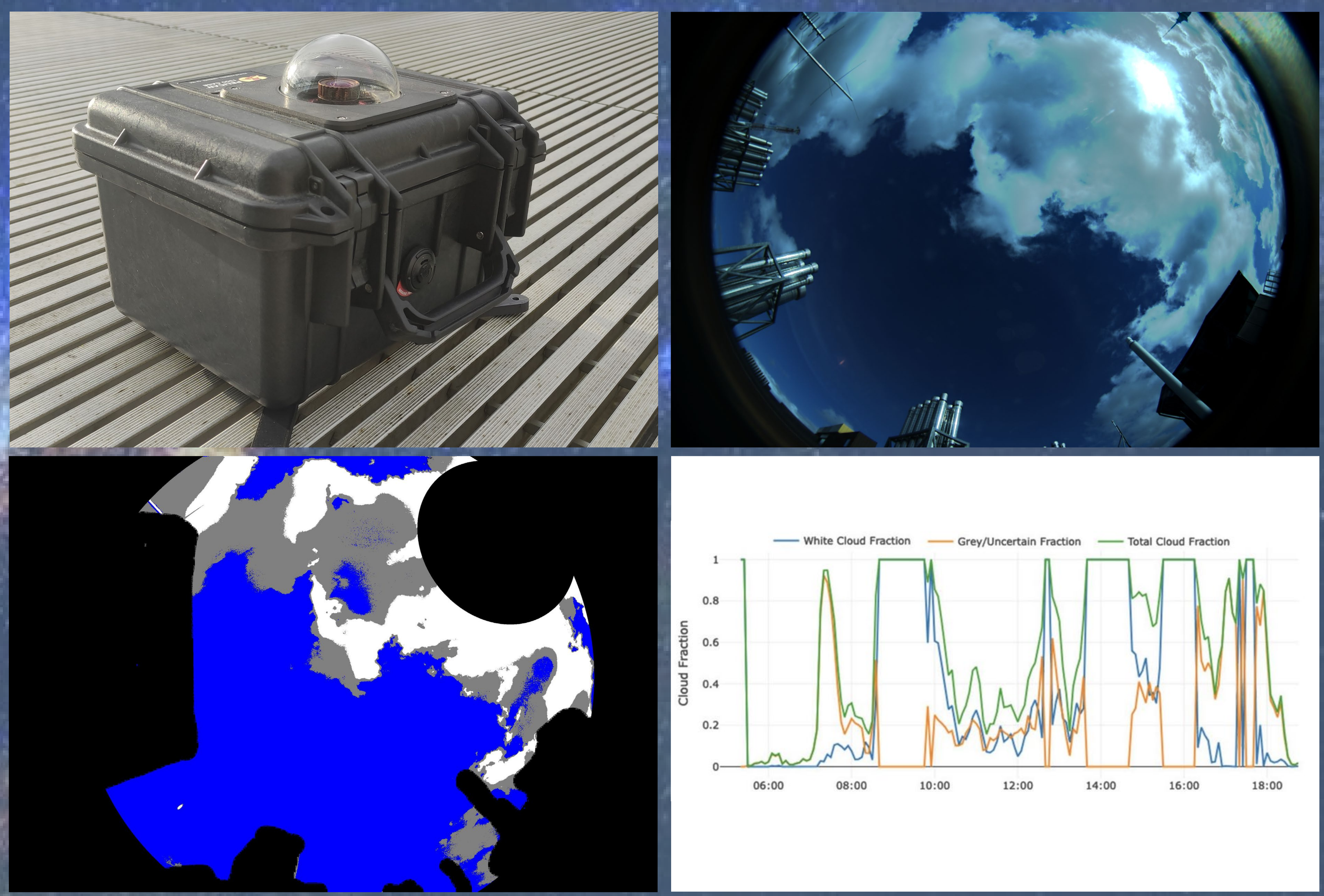
Free Space Optical Communications (FSOC) is the next revolution in high-bandwidth satellite-to-earth data transmission. The critical challenge facing the widespread, commercial adoption of FSOC is requirement of a cloud-free line of sight (CFLOS) between the spaceborne asset and the optical ground station (OGS). One solution to this problem is the use of multiple OGSs in a geographically distributed network. Such networks include the European Optical Nucleus Network (EONN) and the Australasian Optical Ground Station Network (AOGSN). To transition from research to commercialization will necessitate an increase in the number of OGSs and their continuous operation. Automation will play a critical role in enabling 24/7 link availability by reducing the number of required operators per OGS. OGS automation will consist of several discrete control loops including: network-wide astronomical seeing comparisons; assessment of local atmospheric conditions to permit operation; short term cloud cover prediction over the satellite pass; calibration of the pointing model; and tracking the asset pass. Fully automated ground stations would enable near-seamless switching between OGS nodes during a pass, further increasing the link time. The work begun at Taiaho is focused on single-node automation; weather monitoring, cloud predictions, and pass tracking. These goals are achievable through a combination of modern hardware and software, including a state-of-the-art weather and atmospheric turbulence monitoring station (ISM, Miratlas SAS), a direct-drive telescope mount with integrated pointing model (L350, Planewave Instruments Inc.), and a custom software framework linking these with a command-and-control suite.

Cloud Monitoring

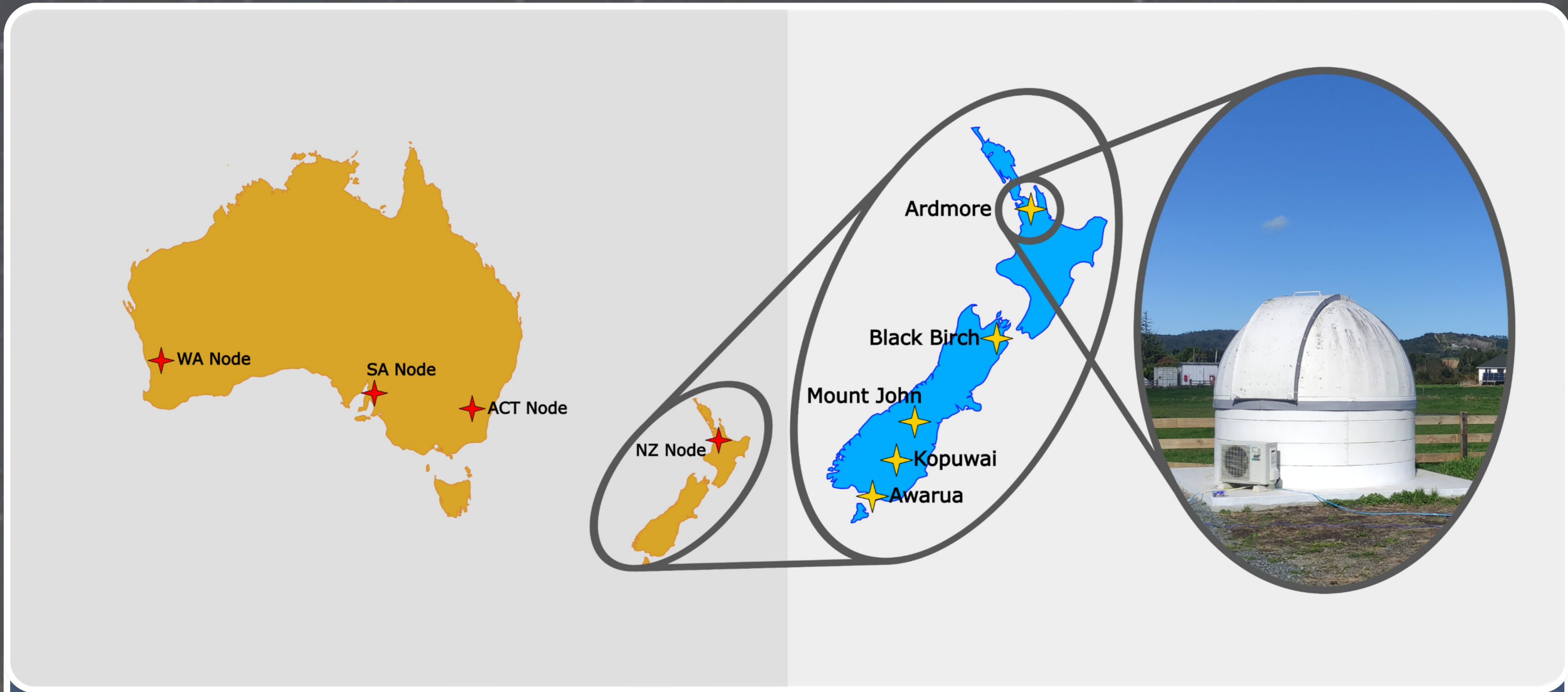
CFLOS is the most important factor in predicted downlink quality. As such, a large part of the Taiaho project is dedicated to the acquisition and analysis of all sky images.

Our site assessment/selection includes the establishment of a network of rugged all sky camera (top left) provided by the National Institute of Water and Atmospheric Research. These cameras acquire images every 5 minutes for time periods of up to 1-2 years, allowing us to characterize the local microclimate at each site.

These images are being used to train a machine learning model, with which we hope to predict the short-term (<30 minutes) motion of clouds. Overlaying this with the predicted satellite pass will give us our key node selection metric, a predicted CFLOS from each node in the satellite path.



Top left: a NIWA all sky camera. Top right: all sky image taken from central Auckland (roof of the physics building).
Bottom left: processed all sky image showing detected cloud cover (note masks for terrain and the sun).
Bottom right: graph showing cloud cover percentage over central Auckland for the course of a day.



Australasian Optical Ground Station Network (AOGSN)

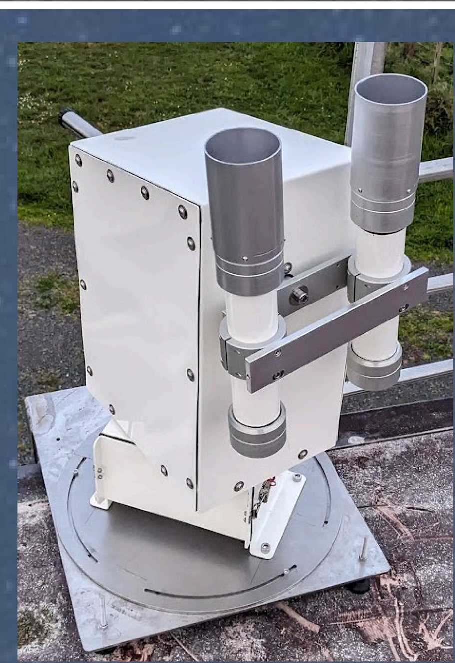
The AOGSN currently spans the length of Australia, currently comprised of: Australian National University's Quantum Optical Ground Station, the University of Western Australia's TeraNet-1 OGS, and a node operated by the Australian Government Department of Defense Science and Technology. The full list of collaborators at the DLR and AOGSN are co-authors of a recent paper (linked on the right), which gives a detailed update on the DLR and AOGSN development.

https://arxiv.org/abs/2402.13282

Atmospheric Turbulence

The Taiaho observatory also includes a Miratlas ISM, the latest in meteorological and atmospheric monitoring. The key instrument in the Miratlas' setup is the Compact Differential Image Motion Monitor (C-DIMM) shown here mounted on a rooftop ~10m from the dome. This dual-telescope setup takes simultaneous video of bright stars, and the difference in their time-averaged apparent motion is directly related to the turbulence in the atmosphere, or the astronomical seeing value.

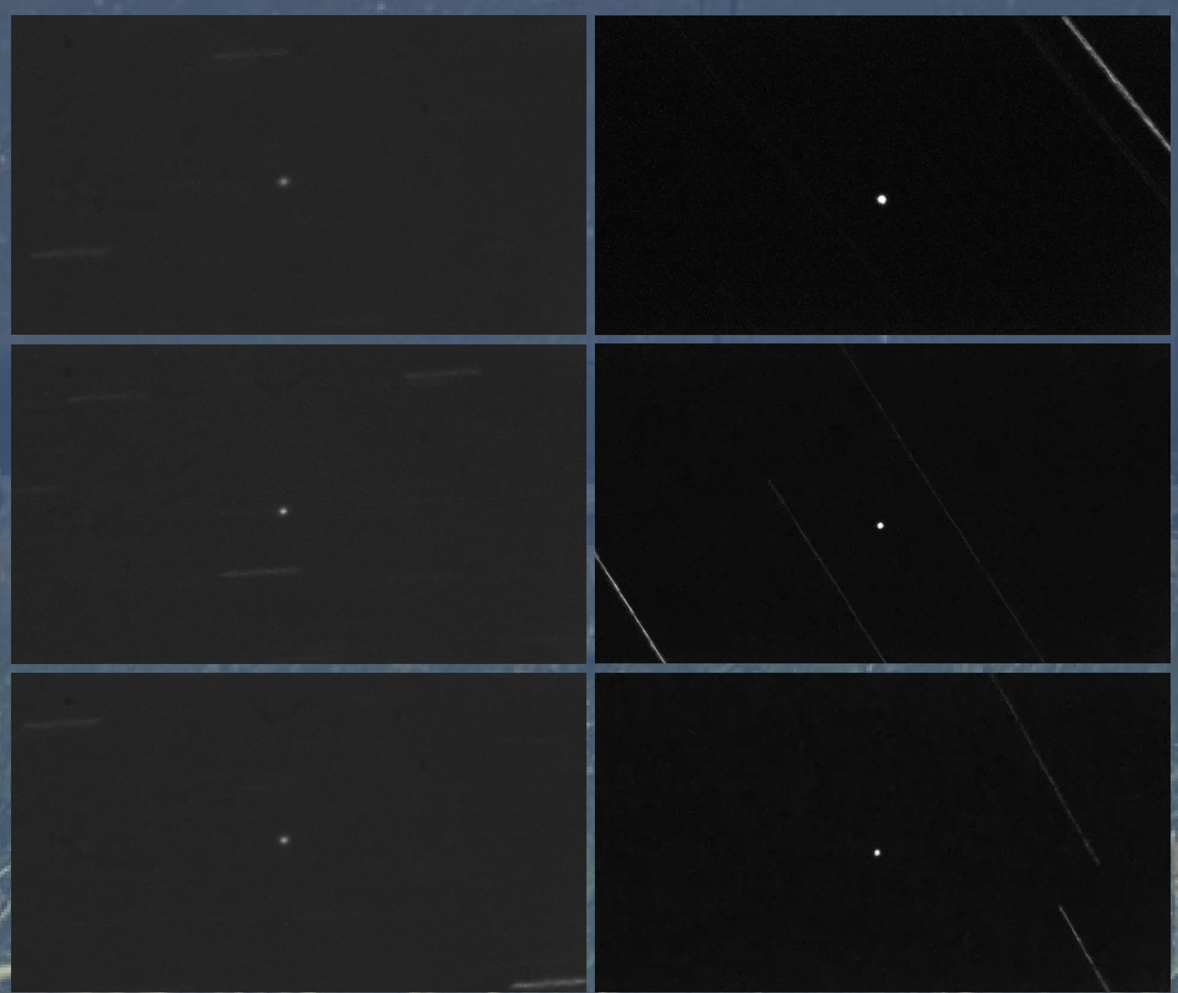
Having the C-DIMM mounted on a small telescope mount enables its use in the southern hemisphere (where we have no fixed star like Polaris) and further allows us to study differences in seeing across the night sky. Low seeing values are expected to correlate highly with optical downlink quality, and will be an important factor in our automated node selection algorithm, second only to CFLOS.



Left: C-DIMM mounted on an Alt-Az mount at the Ardmore field site.

Above: Miratlas ISM central unit, showing all sky camera and sensor suite.

Satellite Tracking



Using publicly available Two-Line Elements we have been able to track both Low Earth Orbit and Geosynchronous Orbit satellites, demonstrating the quality of tracking provided by the L-350 mount, and associated pointing model software.

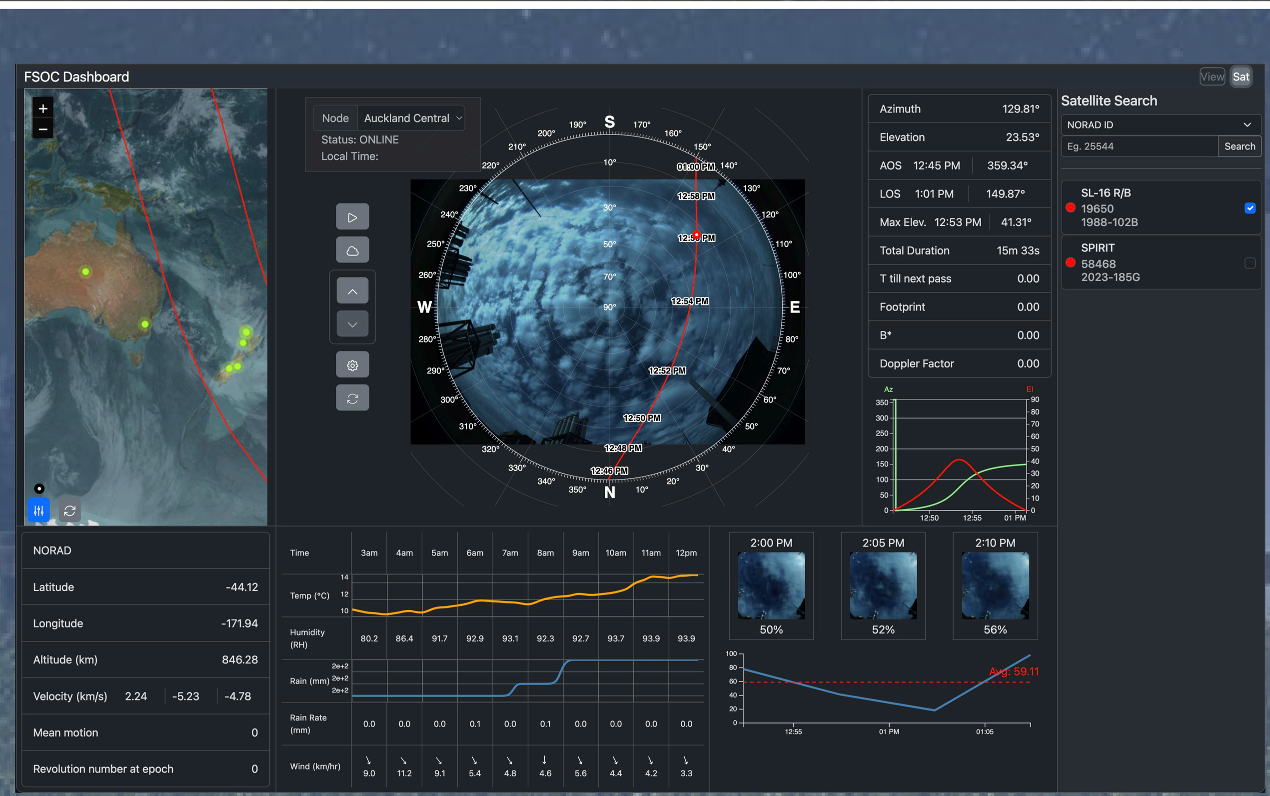
The SOFA unit contains two cameras, one visible light, the other infra-red, which will provide the necessary feedback for closed-loop tracking of FSOC satellites and increased precision for higher downlink quality.

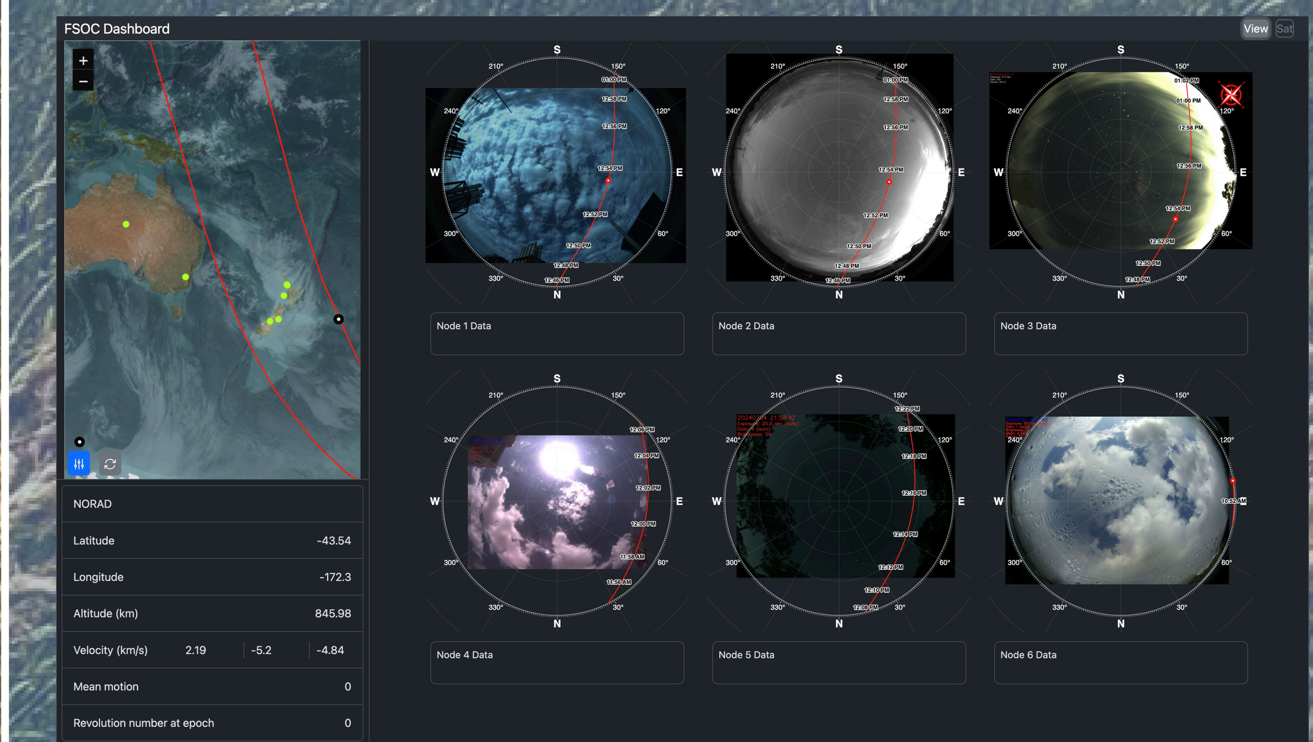
Left: Frames from tracking of TJS-10, GSO satellite

Right; Frames from tracking of GONETS-M 7, LEO satellite

Taiaho Observatory Youtube Channel, for full pass videos.

Data Compilation and Control





Our dashboard compiles data from all our instruments and incorporates them with a satellite pass predictor to allow for simple decisions for downlink viability on an individual node basis. This functionality will be extended to encompass all the nodes in the AOGSN network to enable the automatic selection of an optimal node (or nodes) for any given satellite pass based on the local weather and the estimated CFLOS.

Top Left – Dashboard for a single node. Showing: the node location, all sky image with predicted next pass, selected satellite location information, satellite search tool, weather information, and predicted cloud cover.

Bottom left – Dashboard for the whole network. Showing: node locations, current all sky images with overlayed satellite pass, and selected satellite information.

Live demo of the FSOC dashboard (early alpha, not optimised for mobiles)

Funders/collaborators

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