Development of an Antenna Positioner for S- and X-Band Ground Segment

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Through careful engineering and a little serendipity we have designed and built a commercial-grade 3.7 m S/X- band antenna, positioning system, full predictive ACU and scheduler from a mix of surplus and cheaply sourced parts. The predictive ACU is ready for commercialisation.

CONTROLLER FEATURES

- Smooth track algorithm provides continual movement without stop-starts, even for discontinuous input streams, giving tenfold reduction in TLE propagation computation effort
- Multi thread – prioritises pointing accuracy
- Vigorous 2000 line+ software development, including testing strategy
- Configurable pointing resolution, currently 0.025°
- Pointing accuracy of better than ± 0.1°
- Onboard fault diagnostics
- Works with any DC motor
- Web interface for fast diagnostics and UI
- Accepts input by human-readable TCP and serial commands
- Simple human readable JSON command structure
- Built-in capability to support any of the major antenna positioner protocols.

LAUNCH

The University of Canterbury Rocketry group launch small sounding rockets to test guidance, navigation and control (GNC) algorithms. Being a university, we didn't quite have the capital to outright buy a ground station, so in classic 'Kiwi' (New Zealand) "Number 8" wire style we came up with an innovative, affordable solution to build our own system.

We teamed up with Great South, New Zealand's Ground Segment experts at Awarua in the very south of New Zealand. Awarua has low radio noise and good radio spectrum access, making it a perfect place for spacecraft telecommunications.

RECYCLING

Electronics and software have changed over the last 60 years, but the mechanical requirements of tracking a satellite have remained constant. It so happens that there are a few redundant positioners sitting in storage yards around the country. The chosen positioner tackled for this restoration project was a 1960's Cossor sourced from a friendly research institution. The Cossor features a dual drive on the azimuth suitable for radar applications at 12 RPM and fine track limited to 5 °/s in both elevation and azimuth. The fine track mode is ideal for satellite tracking.

ON REFLECTION

The original Cossor antenna used a 2.1 m Cassegrain reflector, which is too small for many small satellite missions. The affordable standard for small satellites is 3.7 m. Therefore, we purchased a Huaxin 3.7 m reflector designed for fixed Geostationary satellite use. Originally constructed in the 1960's the solid frame of the Cossor positioner needed very little adjustment. The Huaxin reflector was bolted to the front of the positioner and counterweights at the back were added.

FEEDING THE BEAST

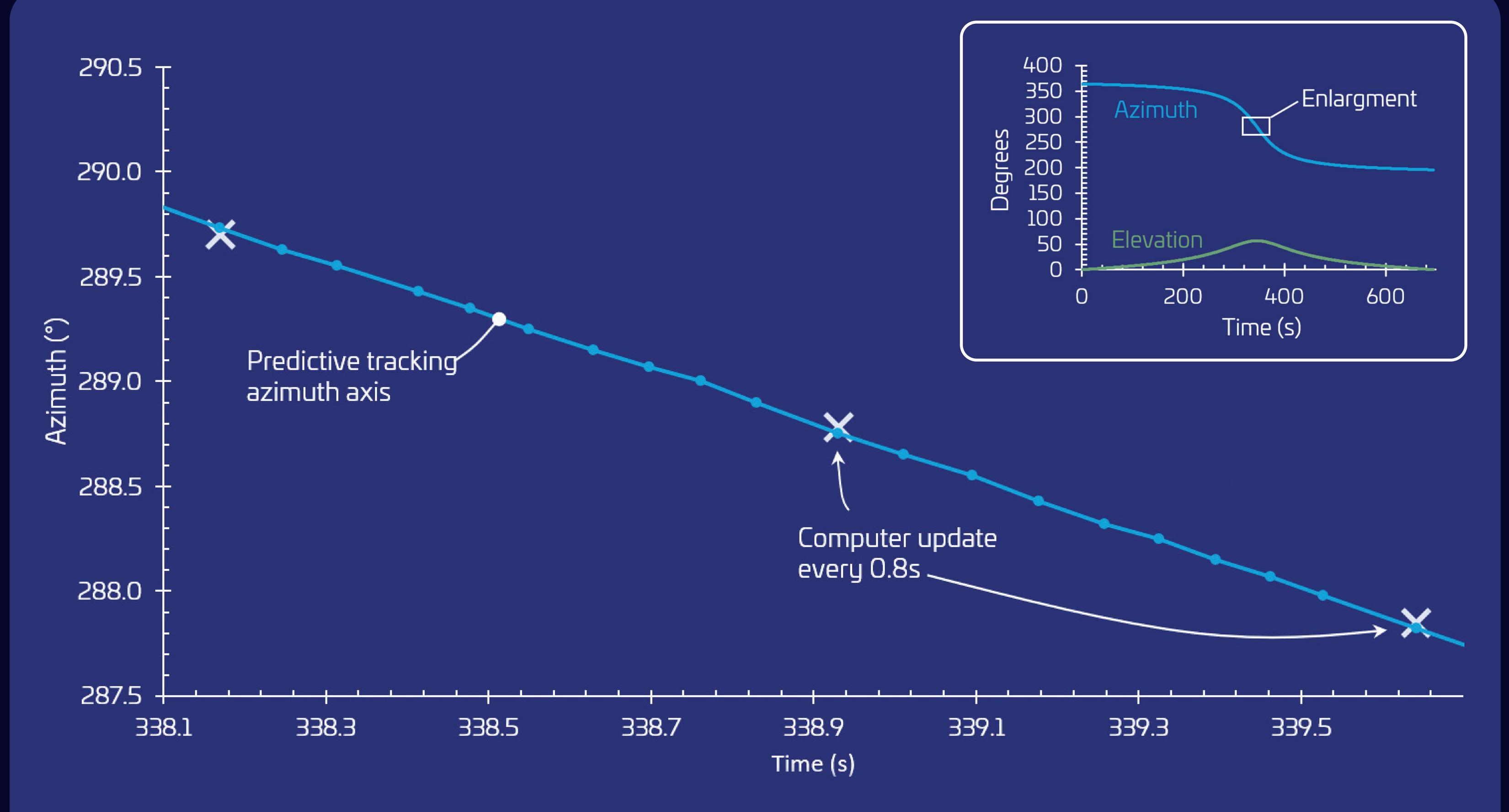
Feeds are notoriously expensive and tricky to obtain. Ryan Hall from the University of Canterbury joined our team and constructed a novel dual-band feed which combines a S–Band patch with a X-Band horn. This approach is an extremely elegant solution allowing dual polarisation, dual band reception and accommodates up to 100 Watts transmission at S–Band. At one time S-Band was used for cellular telephones in New Zealand allowing us to adapt significant advances in this field. For example, our 47 dBm amplifier is recycled from a redundant cell phone site.

STAYING IN CONTROL

Our positioner is driven by DC servo motors, typical of many positioners on the market. The analogue Selsyn position feedback was replaced by optical encoders and an interrupt-driven microprocessor. On a Texas Instrument microcontroller: the encoders are connected as inputs, the limit switches are directed to the board and it outputs a Pulse Width Modulated (PWM) current to the DC motors. This arrangement means the control board is easily adapted as an aftermarket upgrade for second-hand positioners and positioners with fewer features.

To interface with the antenna we built up a web interface. It features a raw TCP port for real-time software API control and an html interface that is easy to use. The interface allows technicians to control the positioner and see its status directly from their smartphone, overcoming the typical issue of having the controller stuck inside while servicing an antenna perhaps 100 m distant.

Using careful filtering of previous commands, our system accurately estimates the future track of the positioner. The predictive algorithm means the DC motors provide a continuous movement reducing wear on gears and allowing a reduction in the position command update frequency. With an encoder resolution of 0.025° we consistently measure results better than ± 0.1°, with the error mainly comprising of windage on the 3.7 m reflector.



A sample satellite pass showing the antenna following the predictive ACU algorithm

A TIGHT SCHEDULE

Real-time scheduling and control software has been designed from the bottom up to schedule and execute passes. The system inputs look angles, propagates TLEs and provides a sun- and moon-track capability to assist antenna performance measurements. A key consideration was implementing a priority basis so multiple missions can be run on the same equipment. We intend to automatically create routines to check the calibration and measure antenna performance to maintain a health check of the positioner and RF components.

CONQUERED

We have successfully built the base station for UC Rocketry's telemetry delivery. To achieve a suitable link on a constrained budget we opted to use a second-hand positioner and build a sophisticated ACU. The ACU features a PWM variable speed drive suitable for controlling any DC motor driven pedestal. Control and fault-finding diagnostics are available to field technicians via a web browser on any local network connected device. A novel dual S- and X-Band feed illuminates the antenna. We are working on developing the ACU for ship borne systems and high-altitude pseudo satellites.

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FURTHER INFORMATION

For more information about this project, please contact:
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