TECHNICAL REPORT / SEPTEMBER 2026

ASTRA 100

Prototype design, construction and evaluation

A modular one-metre radio telescope for practical radio astronomy education and experimentation.

The constructed prototype. Project presentation, instrument overview.

Overview

ASTRA 100 combines a segmented parabolic reflector, a pyramidal feedhorn, an azimuth-elevation rotator, and a software-defined radio receiver. The prototype demonstrates affordable construction, modular hardware, field assembly, and acquisition of radio-frequency spectra.

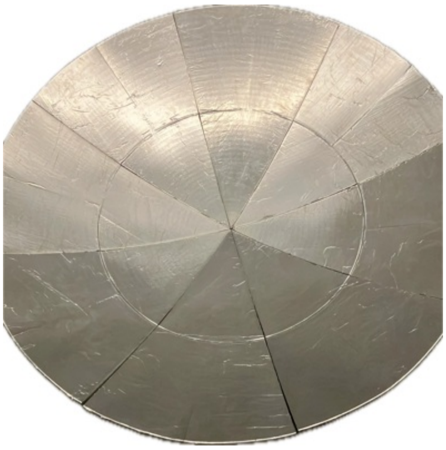
The first field test did not establish a statistically significant neutral-hydrogen detection. Mechanical failures and calibration problems limited the session. A later presentation identifies a receiver frequency-range mismatch. Only one instrument was constructed, so interferometry was not demonstrated.

Documented outcomes: a constructed prototype and recorded spectra. **Development goals:** reliable motorised pointing, validated hydrogen-line observations, and synchronised operation of multiple instruments.

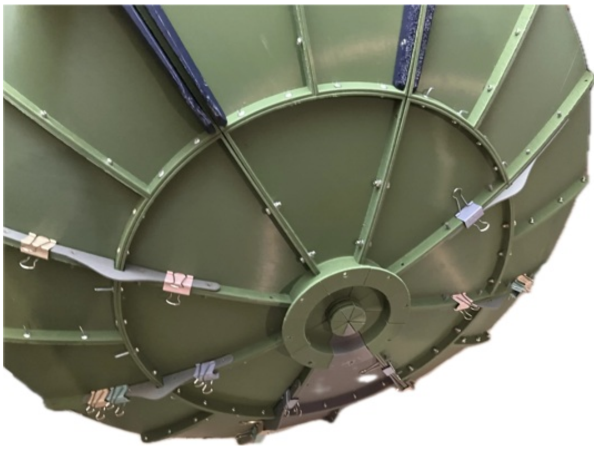
The complete materials list is provided separately in the ASTRA 100 Bill of Materials. This report distinguishes observations, design estimates, and future proposals.

Reflector and support structure

The reflector has a diameter of 1,000 mm and a focal-length-to-diameter ratio of 0.4, corresponding to a nominal focal length of 400 mm. Eight printed segments form the dish. Aluminium tape provides the reflecting surface. A rib structure joins the segments and supports assembly and replacement of individual parts.



Front of the segmented reflector.



Rear structure and radial support ribs.

Dish diameter	1,000 mm
Focal ratio	f/D = 0.4
Nominal focal length	400 mm, derived from diameter and focal ratio
Segmentation	Eight replaceable sections
Main printed material	ABS
Reflecting surface	Hand-applied aluminium tape

Tripod development

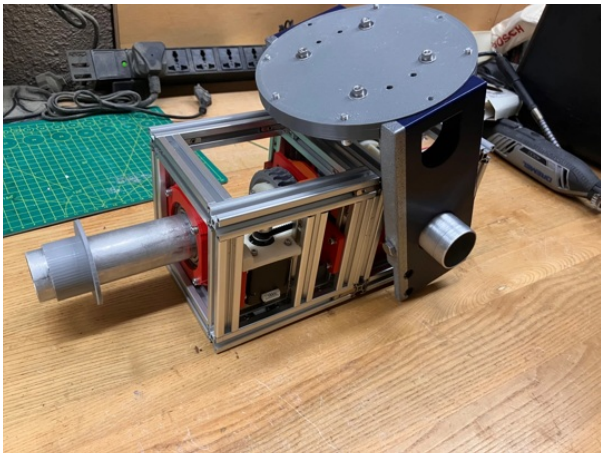
The tripod uses six 30 x 30 mm aluminium profiles in a triangular structure. The design underwent eight iterations to improve rigidity, fastener placement, assembly clearance, and resistance to local breakage. A replaceable collar accommodates the fit between the supporting structure and the rotator pipe.

Early parts were brittle or difficult to secure. Revised connections used larger supporting surfaces and clearer dimensional parameters. The report also records the time and material cost of printing obsolete or unsuitable parts.

Source: original written report, Design and Rationale; Annex 1. Photographs from the project presentation.

Azimuth-elevation rotator

The prototype adapts the SatNOGS Rotator v3 design. Two rotation modules provide azimuth and elevation motion. Each module uses a NEMA 17 stepper motor, a timing-belt stage, and a worm-gear stage.



The assembled rotator and its supporting frame.

A bolted connection introduced to reduce slipping.

Belt stage	36 / 20 = 1.8:1
Worm stage	30:1
Combined reduction	1.8 x 30 = 54:1
Motor holding torque	0.52 N m, as specified in the project source
Ideal static output estimate	0.52 x 54 = 28.08 N m
Estimate at assumed 80% efficiency	22.46 N m

The torque values are design estimates, not measured dynamic performance. Holding torque, gearing efficiency, material strength, mounting rigidity, and load balance must be evaluated separately.

Set screws allowed parts to slip on the rotating pipe, so the design added M8 bolts. Field testing nevertheless exposed weaknesses in the mounting plate, worm gear, and fastener retention. A sufficient nominal torque estimate did not establish adequate mechanical reliability.

Source: original written report, Base Design and Rationale; first field-test evaluation.

Pyramidal feedhorn

The feedhorn is intended to receive radiation focused by the reflector. The design uses a rectangular waveguide, a flared horn, an aluminium-lined surface, and a copper probe. Reinforcing ribs help the printed structure retain its shape.

External feedhorn structure and reinforcing ribs.

The aluminium-lined interior and receiving probe.

Waveguide internal width x height	165.1 x 82.55 mm
Waveguide length	90 mm
Horn mouth internal width x height	199 x 167 mm
Flare perpendicular length	211.1 mm
Probe distance from back wall	34.3 mm
Nominal probe length	52.75 mm

The source describes a nominal -10 dB edge-taper design objective. The mounting arrangement permits adjustment of the feed position along three axes so that its placement can be evaluated experimentally. Its mass and leverage also create a mechanical burden on the mount.

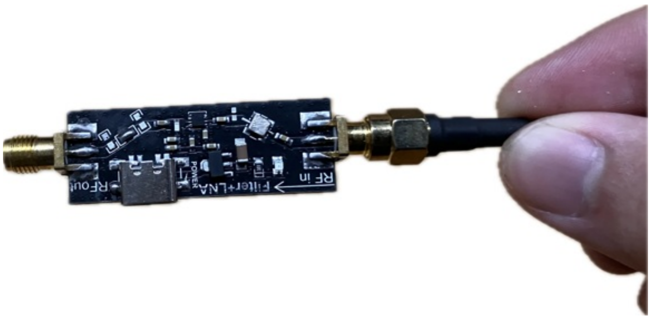
The receiver-parts list separately describes a 50 mm copper pin intended for adjustment. The 52.75 mm nominal design length above and the purchasing description should be reconciled before fabrication. These dimensions are documented design values, not a validated final RF configuration.

Source: original written report, Feedhorn Dimensions and Rationale; Electronics Pipeline.

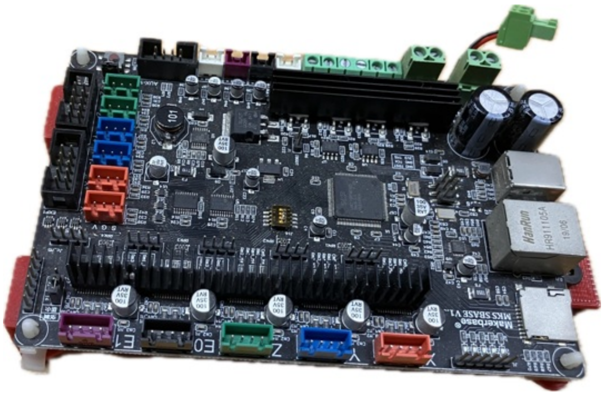
Receiver and motor control

The receiving chain runs from the copper probe through an N-type connection and SMA adapter, a low-noise amplifier (LNA) with bandpass filtering, coaxial cable, and an SDR connected to a computer. The LNA and motor controller have separate power requirements.

Receiving probe	Copper pin in the feedhorn
RF connections	N-type panel mount, N-type-to-SMA adapter, coaxial cable
LNA and filter	Source specification: 18 dB gain, noise figure at most 1 dB; filtering around 1420 MHz
Original receiver	Listed as RTL-SDR V2 in the prototype bill
Mount controller	Makerbase SBASE V1.3
Motor command path	Computer to SBASE over USB serial using GRBL G-code



Low-noise amplifier and filtering hardware.



Combined motor controller and driver.

Receiver compatibility finding

The later presentation identifies an FC0013-based tuner whose stated operating range did not cover the 1420.4 MHz observing target. It reports that an RTL-SDR V4 had been ordered. No validated observation with the replacement appears in the supplied materials.

> The original SDR remains in the historical bill of materials because it was part of the prototype cost. Its inclusion is not a recommendation for a new hydrogen-line receiver. Verify the exact tuner, supported frequency range, driver, and operating behaviour before purchase.

Sources: original written report, Electronics Pipeline and Annex 7; presentation slides 31-33.

Acquisition and calibration

GNU Radio Companion provides the signal-processing flowgraph. The pipeline converts incoming SDR samples into frequency-domain spectra, displays relative signal and receiver-related quantities, and records data in HDF5 files for later analysis.

The report describes adapting an existing spectrometer flowgraph to the available receiver. The implementation used an FFT with a Blackman-Harris window instead of the source design's polyphase filter arrangement. This choice changes spectral leakage and resolution behaviour and must be accounted for in interpretation.

Hot/cold calibration

The flowgraph included calibration using a warmer reference and a cooler sky reference. The source used nominal values of 300 K and 10 K in the calibration logic. Those values were assumptions in the implementation, not independently established temperatures for the actual field references.

During the test, vegetation substituted for a controlled absorbing target. The recorded outputs remained in relative units after calibration. A smoother spectrum alone therefore does not establish an absolute temperature calibration or an astronomical detection.

Rotator control

A Python interface communicates with the SBASE controller using human-readable GRBL G-code commands over USB serial. Calibration relates commanded motor steps to actual telescope angles. Pointing logs could later be paired with signal-power measurements for controlled scans.

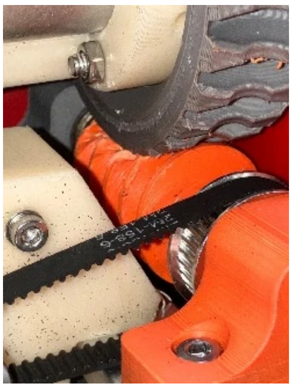
Measurement requirement	Evidence needed
Receiver frequency coverage	A verified operating receiver chain at the target frequency
Calibration	Repeatable references, known settings, and interpretable units
Pointing	A reliable relationship between commanded and measured angles
Astronomical detection	A repeatable calibrated feature distinguishable from instrument artifacts and local interference

Sources: original written report, Software; Annexes 6, 7 and 9. The measurement requirements above synthesise the limitations documented in those sections.

First field test

The recorded session ran from 23:00 on 2 August to 04:00 on 3 August. The instrument was transported, assembled outside the workshop, and used to record spectra. This established a practical assembly and data-acquisition workflow, while revealing important mechanical and electrical limitations.

Stage	Finding and response
Before deployment	The rotator-to-tripod connection broke. Direct insertion of the rotator into the tripod provided a more stable temporary arrangement.
Mechanical assembly	Access to dish fasteners was difficult. Feedhorn assembly also required improvement, with a clip-on arrangement proposed.
Motor power	The vehicle supply measured 14.6 V rather than the expected 12 V. The controller did not drive the motors; voltage protection was suspected but not established.
LNA power	The initial power-bank connection did not supply the LNA. A different USB-C cable arrangement provided power.
Observation	Motor control was unavailable, so the instrument was moved manually. Calibration references were not well controlled.
After the session	The worm-gear system failed. Brittle material, loose nuts, load balance, and mounting rigidity were identified as contributing issues.



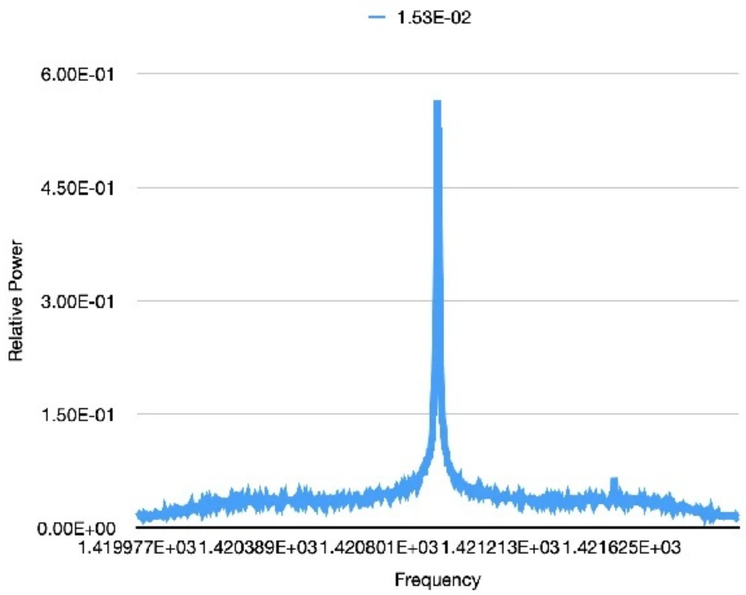
Damaged PLA worm gear documented after testing.

An ABS worm gear documented in the report.

Source: original written report, Evaluation and Annex 1. The recorded session date is retained as part of the experimental record.

Recorded spectra and their limits

The prototype produced HDF5 data and plotted spectra. The prominent feature near 1421 MHz was classified in the project analysis as an instrumental DC spike. No statistically significant neutral-hydrogen feature near 1420.4 MHz was identified after the attempted calibration.



Original raw-spectrum figure. The vertical axis is relative power. The source figure does not explicitly label a frequency unit. The project analysis identifies the peak near 1421 MHz as instrumental.

Objective	Documented outcome
Low-cost construction	Prototype reported at S$300.71, below the S$400 design target
Modularity	Replaceable dish sections, adjustable feed, and independently replaceable electronics
Portability	Field transport and assembly demonstrated
Mechanical reliability	Partially achieved; rotator and support improvements remained necessary
Data acquisition	Recordings and plotted spectra obtained
Hydrogen-line detection	Not demonstrated
Interferometry	Not demonstrated; only one telescope constructed

These results demonstrate useful engineering and acquisition progress. They do not establish calibrated absolute sensitivity, measured angular resolution, or a confirmed astronomical detection.

Sources: original written report, Objectives and Annex 9; presentation slides 31, 37-38 and 43.

Priorities and open questions

The next stage should address the documented limits of the single telescope before treating a distributed network as an operating capability.

Priority	Next step grounded in the project findings
Receiver verification	Confirm target-band coverage and test the replacement receiver as part of the complete RF chain.
Mechanical reliability	Strengthen the rotator and mounting connections, secure fasteners, improve load balance, and reduce feed leverage.
Controlled power	Use appropriate, verified supplies for the motor controller and LNA.
Calibration and repeatability	Improve reference measurements, preserve acquisition settings, and repeat observations before interpreting spectral features.
Pointing and scans	Validate the rotator calibration and associate measured angles with recorded spectra.
Two-instrument experiment	Construct another node and develop timing, synchronisation, raw I/Q recording, and correlation.

Cost context

The recorded line items total RMB 1,582.96. The original source reports S$300.71 for that tally, including shipping and a miscellaneous allowance. This is a historical prototype cost, not a current procurement quote. It does not establish the cost of a revised receiver or a second instrument.

The separate bill of materials reproduces all 43 non-total rows from the source tally. Missing quantities and prices remain explicitly unspecified. A blank price is not treated as a free component.

Distributed observing

The long-term proposal is to let independently built telescopes participate in shared observations. Interferometry would additionally require precise timing, appropriate clocking, preservation of phase information in raw I/Q samples, and a correlation system. These remain development tasks.

> The observed stage of the project is a single prototype. Shared designs and documentation can support reproducibility now, while scientific and multi-instrument capabilities require further validation.

09 / DOCUMENTATION

Sources and scope

This report reorganises the technical content of the supplied project materials. It preserves documented limitations and separates original observations from later findings. It does not introduce new test measurements.

Project sources

Written project report. Design and Rationale; Telescope Metrics and Data Collection; Evaluation; Annex 1 (hardware photographs); Annexes 6-7 (software); Annex 8 (cost tally); Annex 9 (spectra).

Project ASTRA presentation. Instrument photographs and later revisions; slide 31 (receiver diagnosis); slides 35-38 (objective evaluation); slide 43 (remaining limitations).

The cost table and component dimensions come from the written report. The receiver compatibility finding comes from the later presentation. Its replacement order is not evidence of a completed receiver validation.

Technical references retained for further reading

SatNOGS Rotator v3
https://wiki.satnogs.org/SatNOGS_Rotator_v3

Essential Radio Astronomy
https://science.nrao.edu/opportunities/courses/era/

Waveguides
https://www.radartutorial.eu/03.linetheory/Waveguides.en.html

These references were listed in the original project materials. They are provided as further reading; this edition does not claim that their contents or external links have been independently revalidated.

Companion document

ASTRA 100 Bill of Materials contains the full historical component tally, original purchase/use quantities, cost notes, total reconciliation, and qualifications for a future build.

Images

Figures show the project hardware, CAD-derived imagery, and an experimental spectrum. They document the prototype and should not be interpreted as evidence of validated astronomical performance.