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Observatory Automation & Remote Control

Supervisor:
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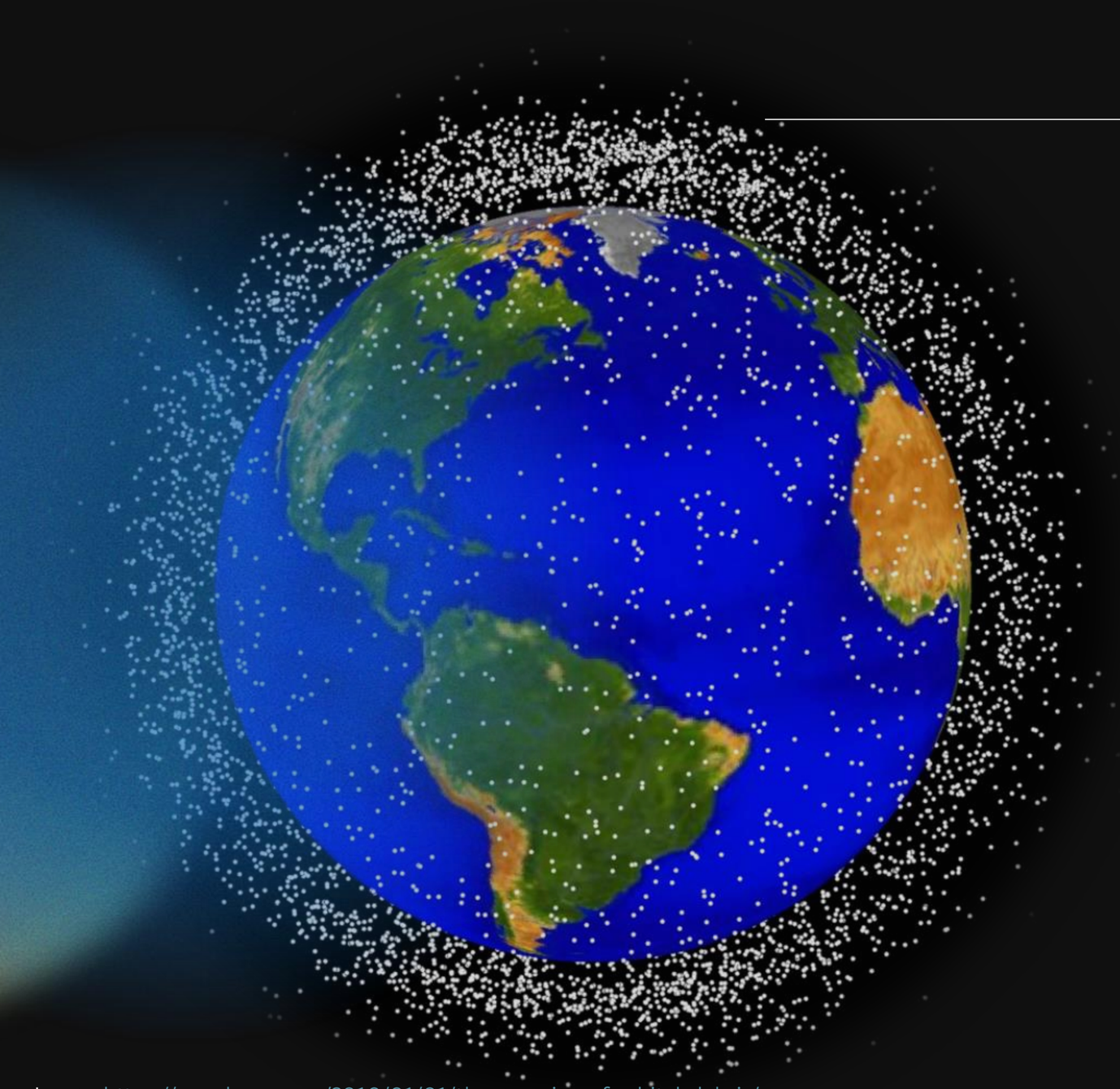
THERE'S NOT MUCH SPACE *IN SPACE.*



- Over 11,000 active satellites
- Over 40,000 tracked objects
- Over 130 million pieces of junk in orbit < 1mm

~ 7.8km/s orbital speed

NEED eyes on the ground to track debris

Image: https://appel.nasa.gov/2010/01/01/the-greening-of-orbital-debris/

Stats: https://sdup.esoc.esa.int/discosweb/statistics/

The observatories need brains ↗

- Space Situational Awareness (SSA) requires automation
  - Point and track objects automatically

Image: https://www.fhr.fraunhofer.de/en/sections/Radar-for-Space-Situational-Awareness-RWL.html

The HQ: K17 Rooftop

Sitting atop the Computer Science and Engineering (CSE) Building, sits the UNSW observatory.

Ideally, this observatory joins the global SSA effort.

So, what's in there?

Image: https://earth.google.com/web/@-33.91884991,151.23109856,58.93182603a,110.90345705d,35y,37.48707737h,61.77731876t,-0r/data=CgRCAggBOgMKATBCAggASg0I_____ARAA

The Eye

Schmidt-Cassegrain Optical Telescope

Aperture
35cm

Focal Length
391mm

Focal Ratio
f/11

Field of View (FoV)
0.17° × 0.17°

https://www.verywellhealth.com/thmb/sMKp2K_OqEe-KTSkQhPuB5e4r2Q=/3891x2190/filters:fill(87E3EF,1)/GettyImages-1176128997-50151a347f6645e98e944a7b55fba595.jpg

The Muscle

10Micron GM2000 HPS II

A German-Equatorial mount built like a tank

Absolute Encoders	Satellite Tracking Capability	50kg Payload Capacity
TCP/IP with Ethernet OR WiFi	Serial Connection with ASCOM	Sub Arcsecond Precision

Image links: https://thefrisky.com/wp-content/uploads/2019/01/musculacion.jpg
https://www.10micron.com/wp-content/uploads/2016/03/GM1000HPS-05-1.jpg

The Retina

ZWO ASI 533MM

- Monochromatic, high-speed CMOS sensor for orbital capture

Okay,
How do we use it?

*It needs some babysitting

The telescope system is great.
The infrastructure was... vintage.

- Manual dome
- Manual shutter
- No sensors
- No control software
- No central computer

Image Link: https://epmgaa.media.clients.ellingtoncms.com/img/photos/2014/08/20/BabySitting.jpg

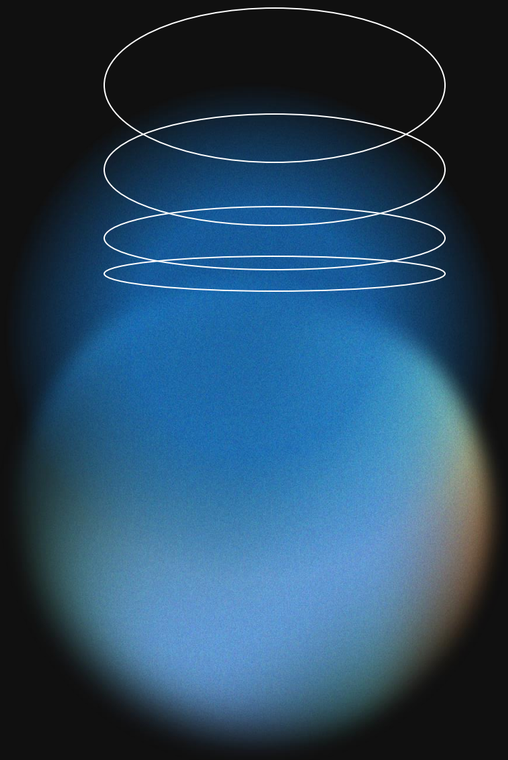
Reality check

Most educational observatories are like this

- Built for a different era
- Dormant, but powerful equipment just asking to enter the modern world
  - SSA
  - Better Educational Tooling

Project Goal

Build a fully remotely usable, automatable system for:



- Telescope Control
- Dome + Shutter Control
- Live Feedback

How did I even start?

A systems engineering approach

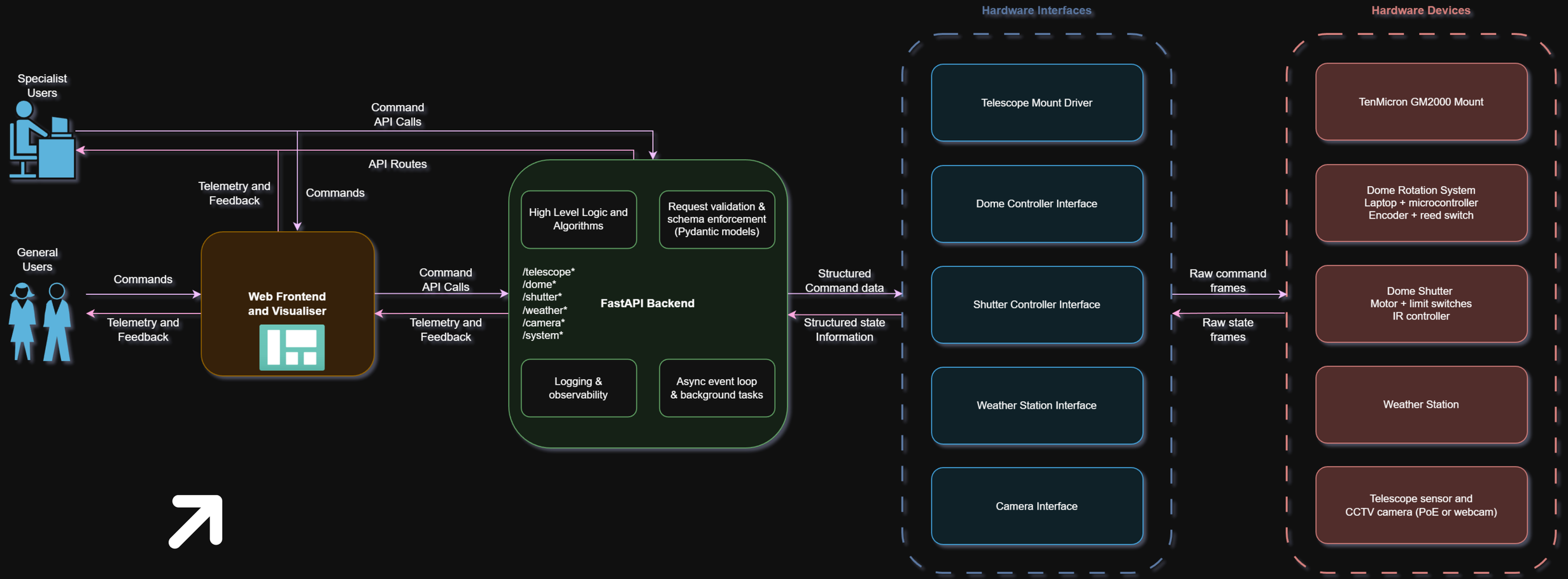
Requirements

Install Hardware

Write Software

Hardware + Software Integration

Testing, Verification & Validation



System Architecture

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Hardware Installs

- Replacement of the 240V AC motor assembly with a DC motor
- Control computer installation (temporarily just my laptop)

Telescope Mount Driver

Talking to the mount without Google Translate

- Handles communication and translation
- I wrote a 1400 line Python package to cover all important mount functionality
- Communicates over TCP/IP Sockets via Ethernet

Taming the Dome

The dome firmware is like a forgetful, hearing-impaired person

- Runs over UDP and IR
- Drops frames frequently
- Custom low-level protocol
- Under active development (changing)

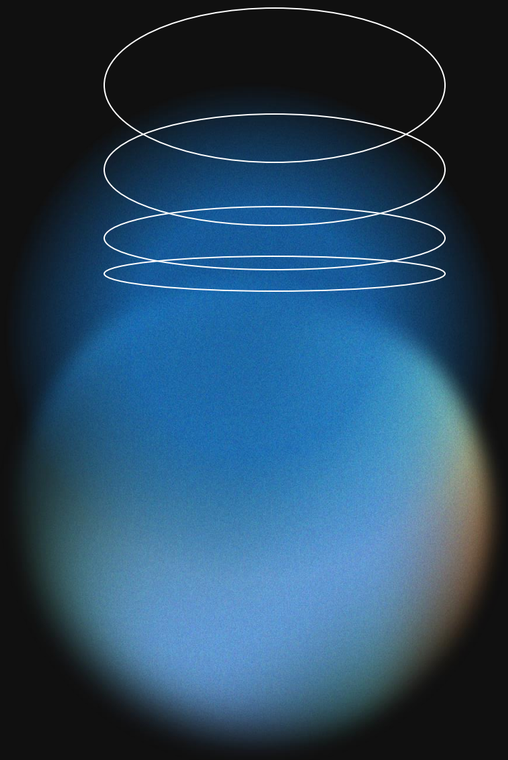
The Brain

The glue holding it all together and doing the thinking

Python + FastAPI powered backend	Non-blocking calls with AsyncIO	Pydantic data validation for safety
Websockets & REST API	Integrated documentation	Runs integration logic such as...

The math of seeing

Dome Synchronisation



↗ Off-Centre

The telescope mount isn’t in the centre of the dome

↗ Changing Pivot

German-Equatorial Mounts have 2 independent axes other than the telescope optical axis

↗ Meridian Flips

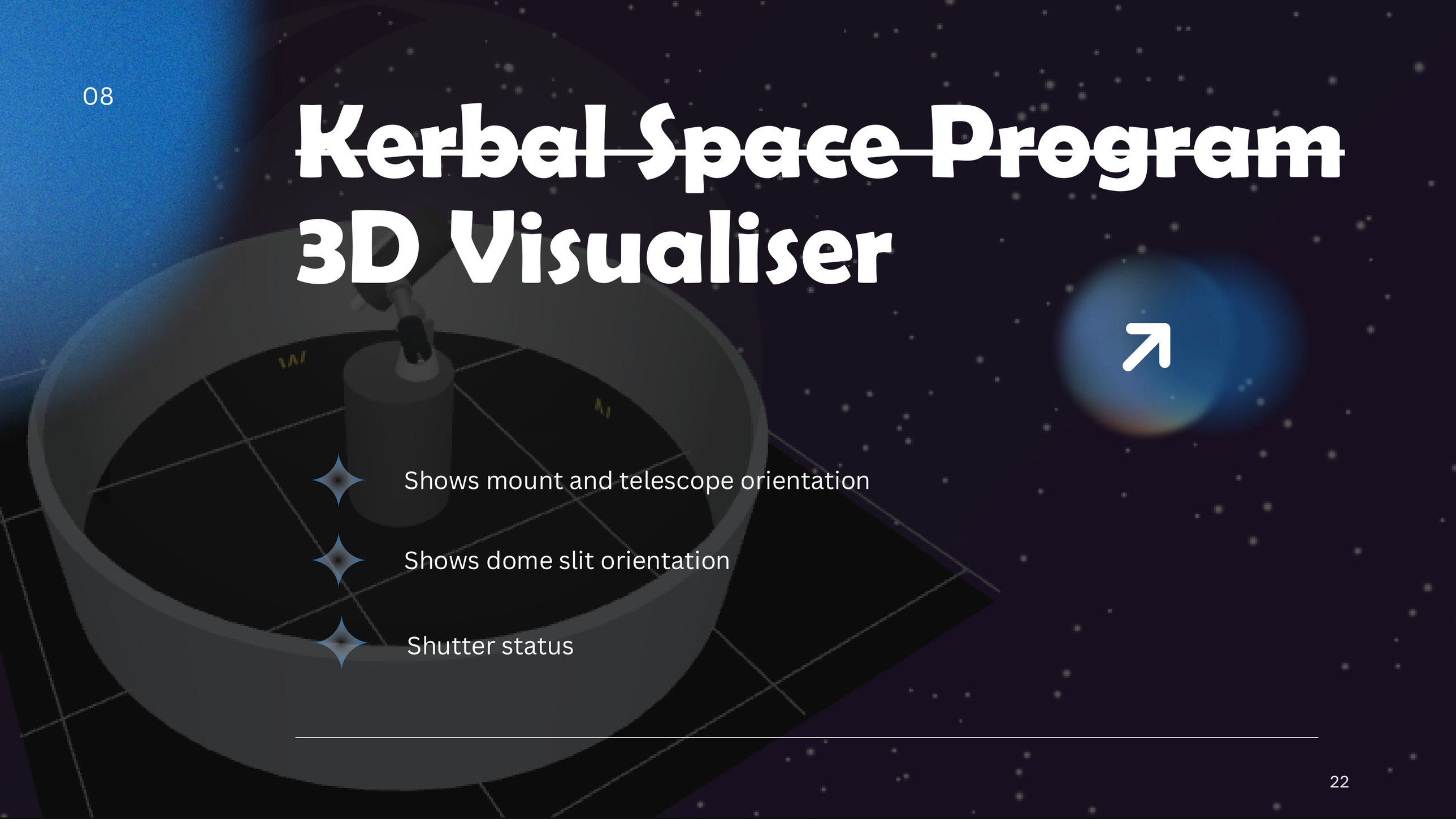
German-Equatorial mounts can flip pier side but point to the same location

Dashboard

Where everything is controlled from

- Control Point
- React and Typescript
- View stats and show live telemetry
- Show camera view of observatory

~~Kerbal Space Program~~ 3D Visualiser



- Shows mount and telescope orientation
- Shows dome slit orientation
- Shutter status

Yeah, but does it actually work?

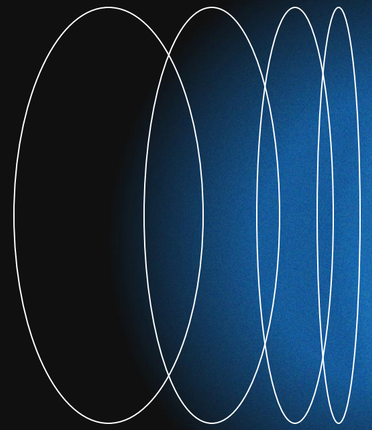
Unit Tests	Software Integration Tests	Hardware-In-Loop Tests
Frontend Usability Tests	End-to-end Operation Tests	But not just that...

Live Demo!

Here we go...

Yeah, pretty much!

- Stable mount control achieved
- Dome synchronisation worked for the two quadrants tested
  - Dome firmware functionality limited
  - The firmware was only completed by a collaborator a few weeks ago
- <300ms local latency
  - Remote latency is variable
- Complete remote control works too!



Educational Benefit

- Remote Learning
- Safe student access
- Real-time interaction
- Visual engagement

Image Link: https://activatelearning.com/wp-content/uploads/2023/06/Student-and-Teacher-with-Telescope.jpg

SSA & Research Impact

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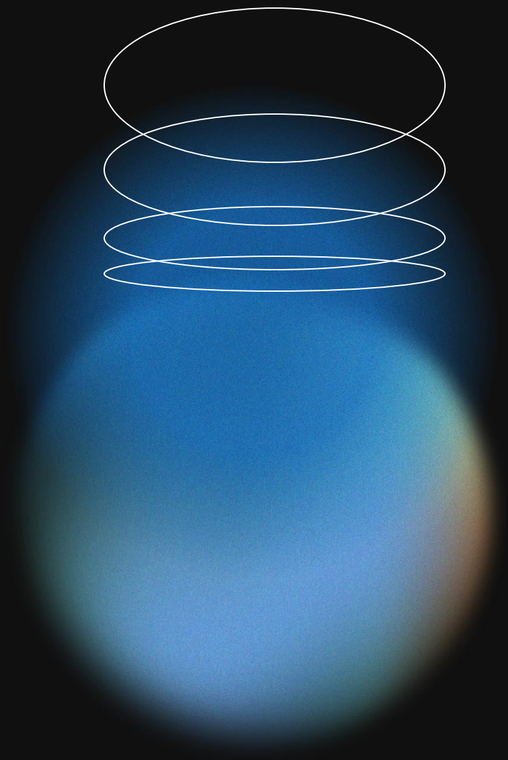
- LEO tracking potential
- TLE-based satellite mode
- Automated observation workflows

So what next?



↗ Hardware Integration

Shutter control
Weather station
Telescope sensor

↗ Computer Installation

Install a central computer
Install data processing node

↗ Make a robot(ic observatory)

Ai assisted task scheduling
Closed-loop image analysis
Automatic SSA node

Thank You