



# Current state of CHARA telescopes & Future plans

The CHARA Science Meeting 2025 - Nice

[https://slides.com/nicscott/chara\\_meeting\\_2025](https://slides.com/nicscott/chara_meeting_2025)

nic scott

Telescope Systems Scientist







but let's assume the best...





Where does CHARA have single point failures....

i.e. where the nightmares lie?

- aging equipment
- time sinks
- lack of spares
- discontinued components
- supply chains becoming questionable
- other risks

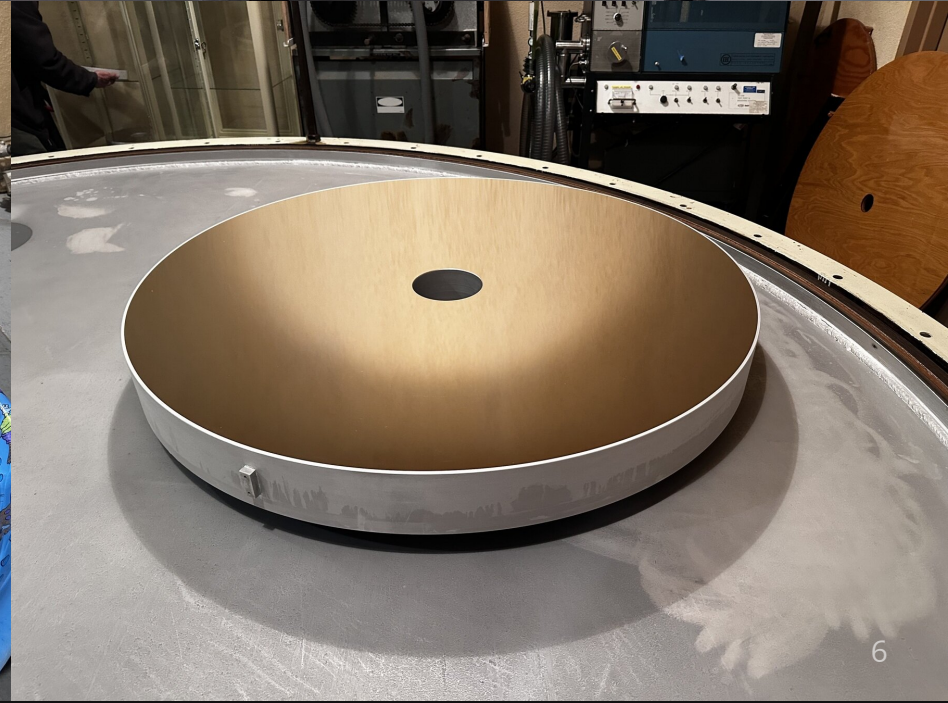
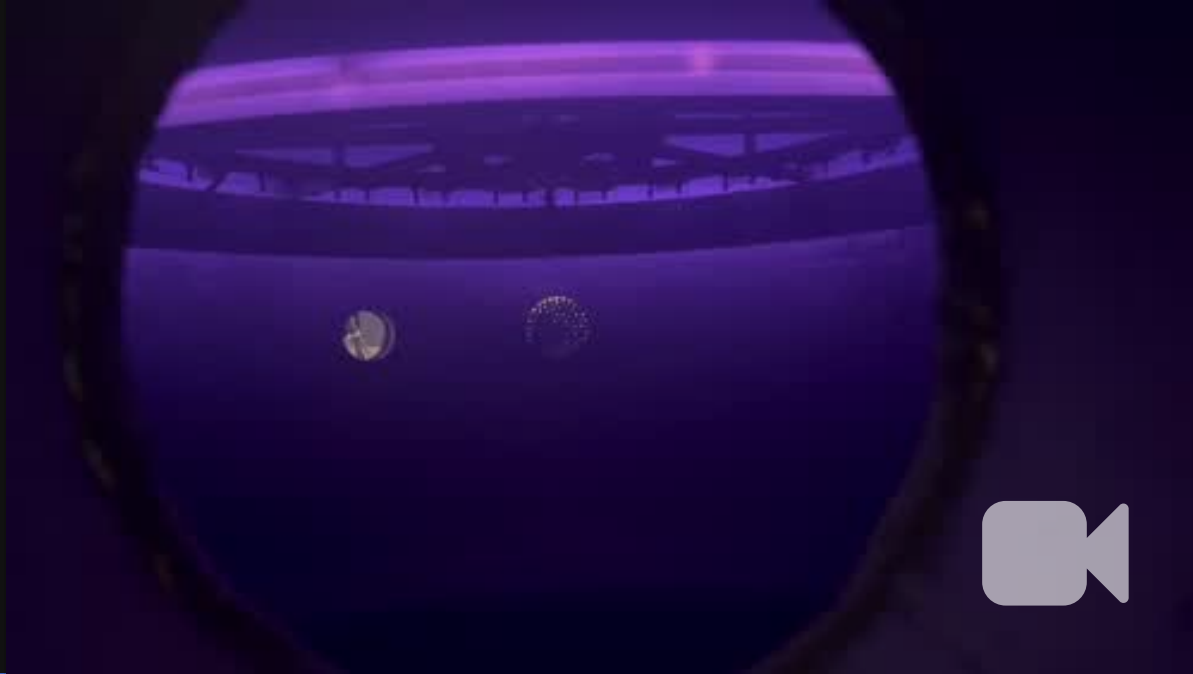
- Mirror recoats
- W1 M5 damage
- Winch system
- New drives
- Stairs & weatherstripping & minions
- Cylinder control
- W1 realignment
- AOB problems and plan for new system
- Tiptilt concerns
- Future



# Mirror recoats

scope	date last done	tbd
S1	4-2022	2026
S2	8-2021	2026
W1	2-2025	2027
W2	9-2019	2025
E1	12-2024	2027
E2	1-2018	2025



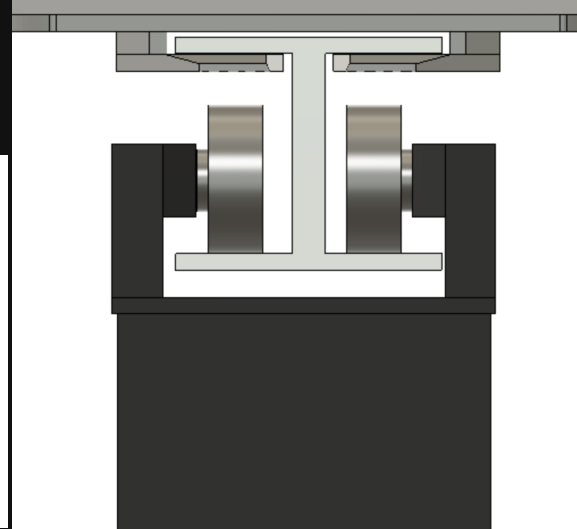
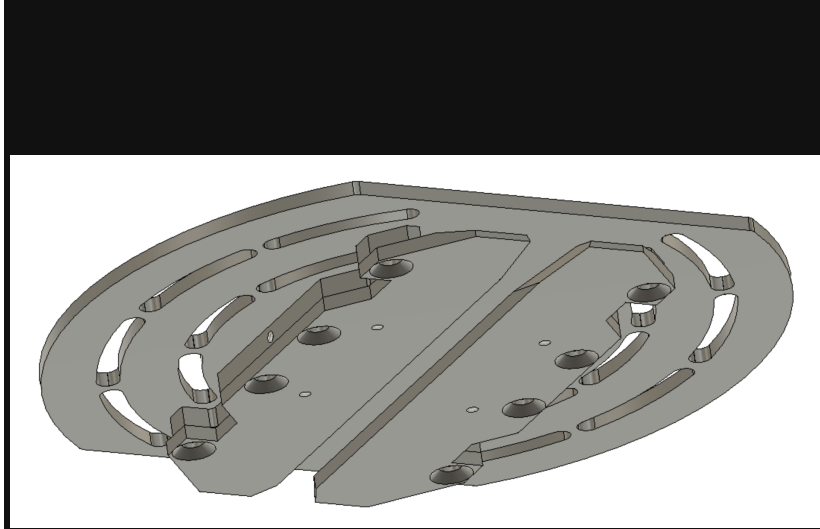
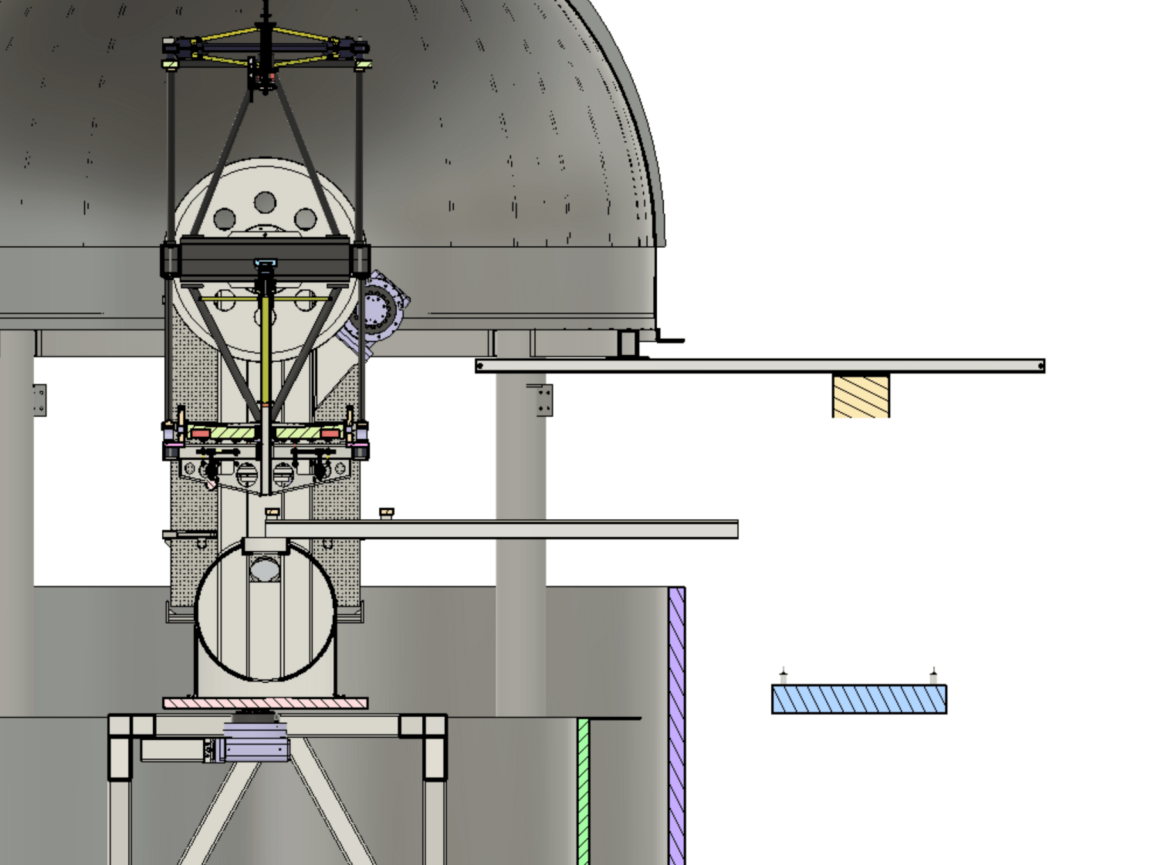
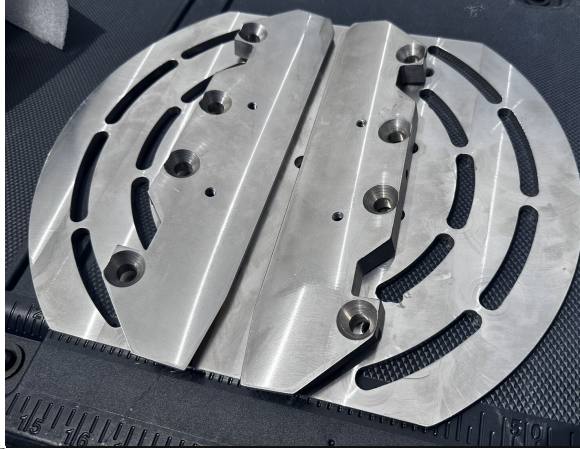
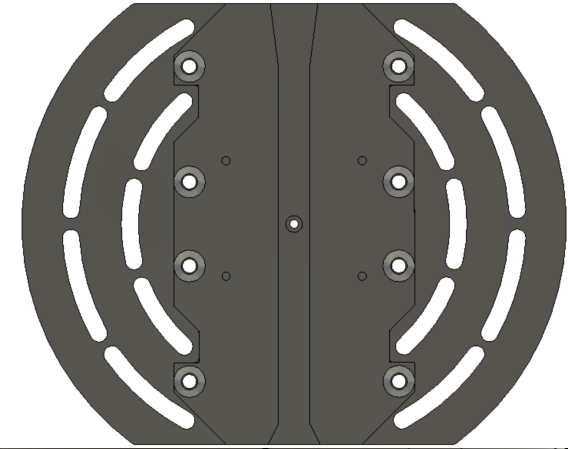




- W1 M5 fracture
  - internal mirror stress
  - cross polarization test
- Replaced with flat M4 -lucky
  - no spare M6 or M2
  - have a matched M1/M2 spare
- Chamber is no longer flat
  - teflon standoffs
- Chamber seal
- Want a small chamber for individual mirror recoats
- Boom truck
  - Genie/rental stop gap
  - new hoist system
  - needed for AZ drive







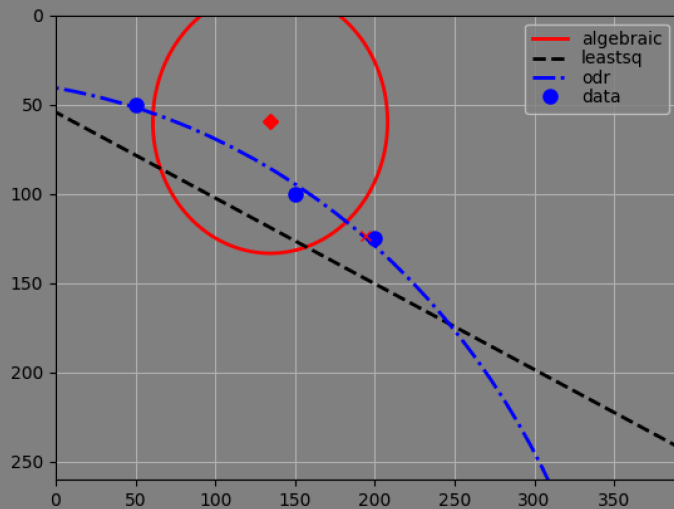
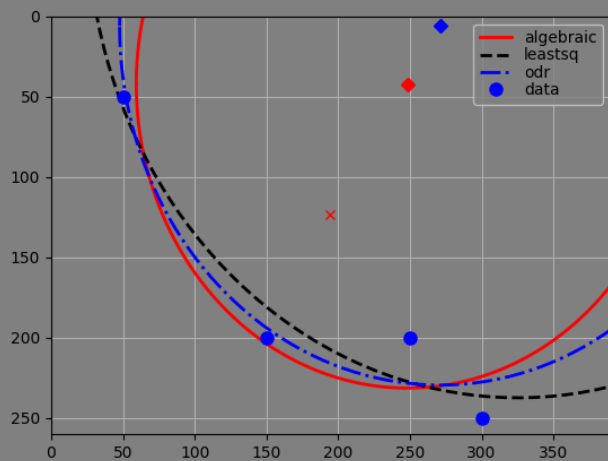
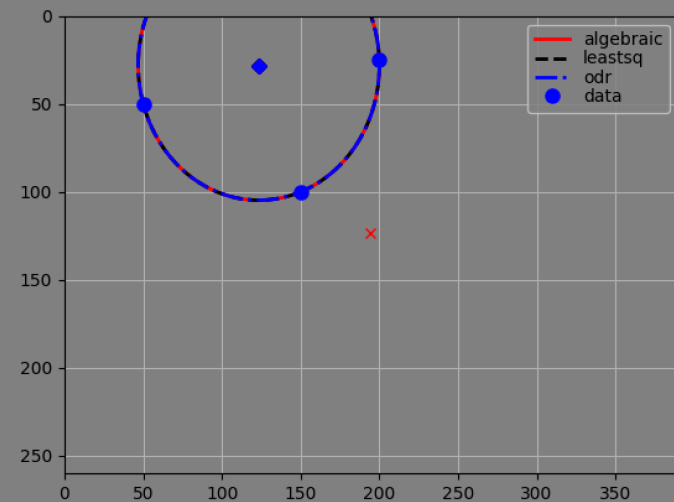
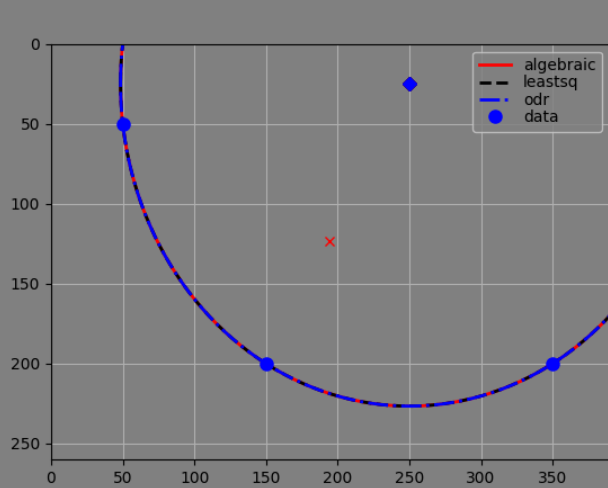
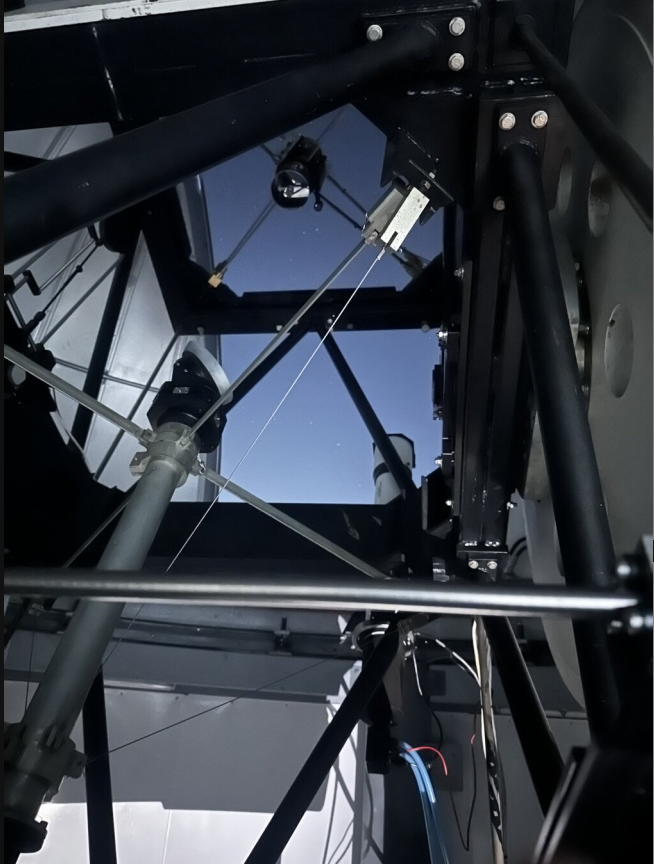


## W2 & E2

- Stairs and crypt platform added for safety
- W2 done, E2 next
- S1 weatherstripping and flashing replaced/repaired
  - needed for all scopes
- Interface plate done for seeing monitor



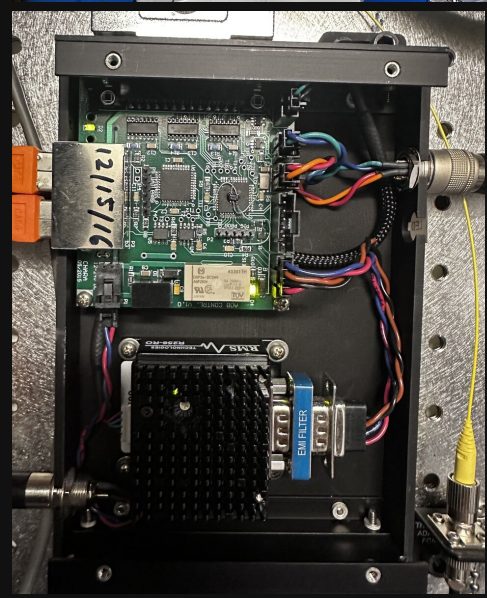
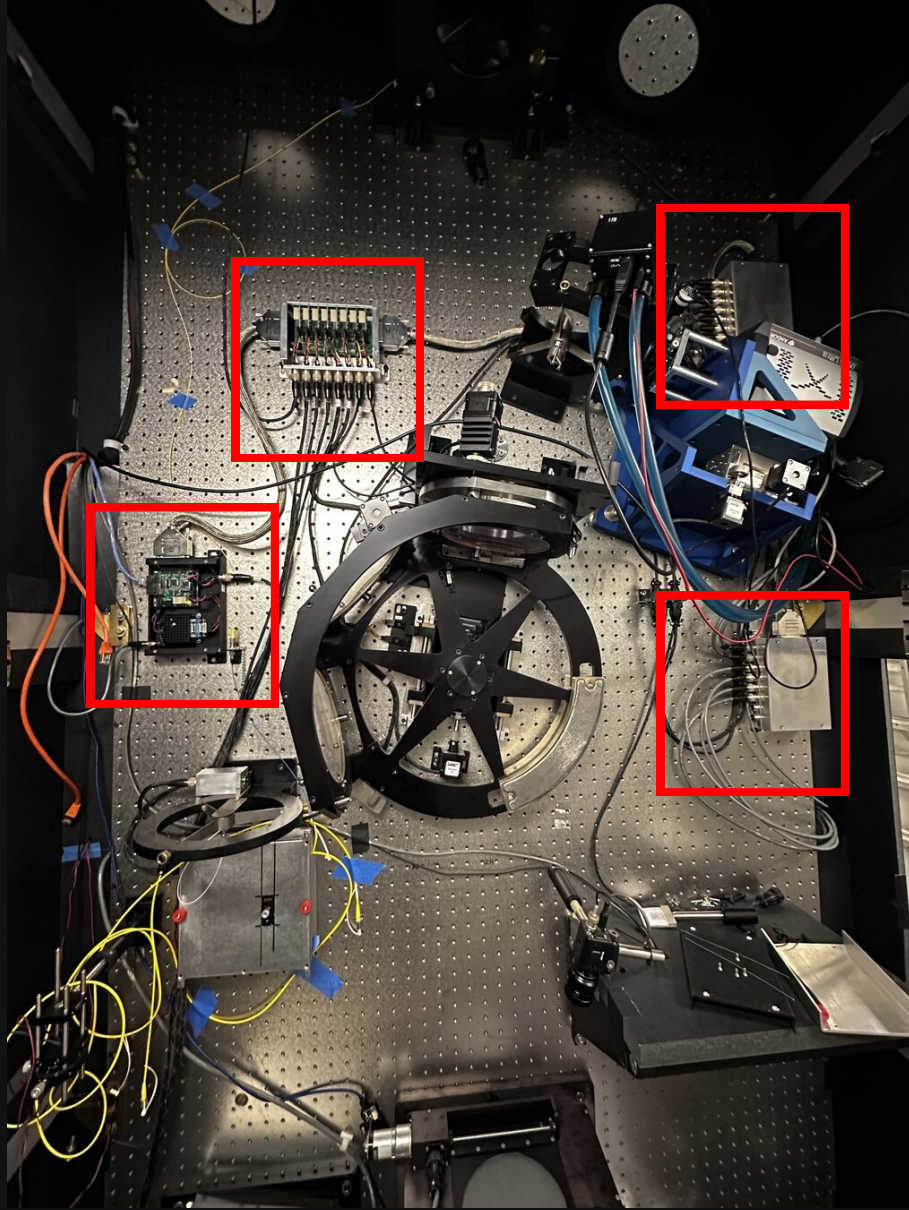




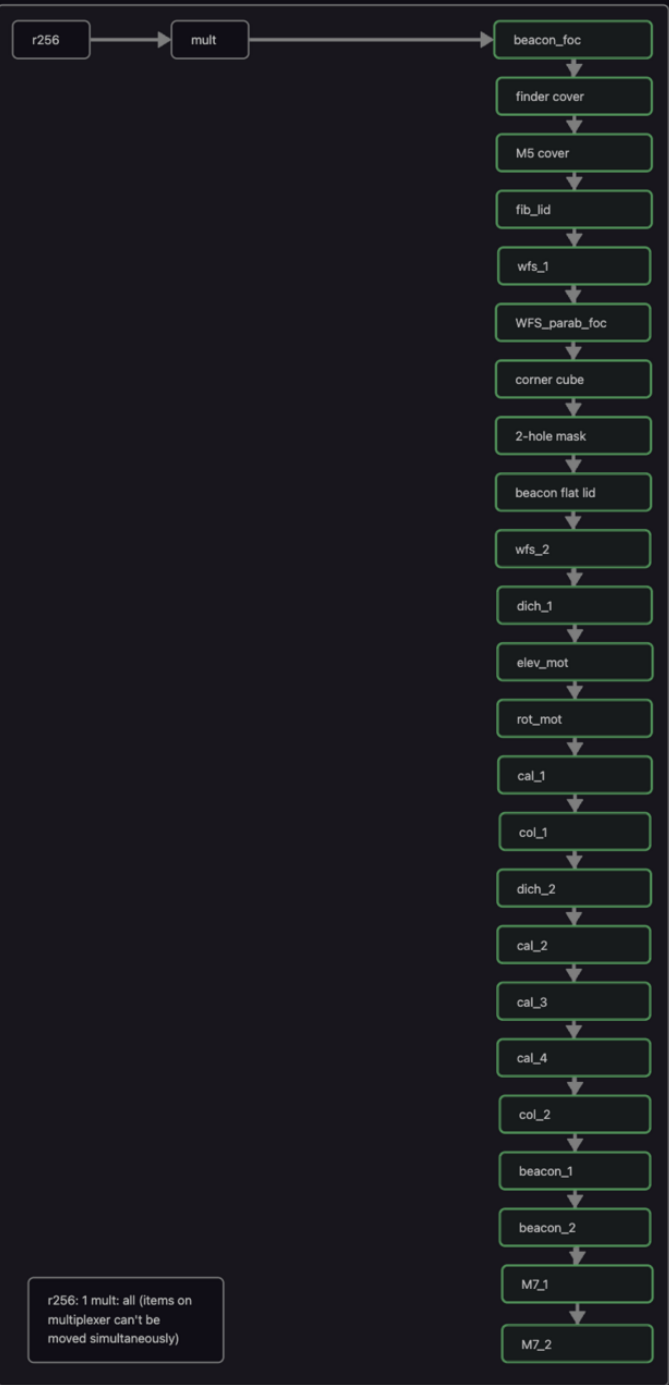
- TelAO instead of TAS for alignment
- circle4.py
- speeds and improves EL axis alignment
- predicting circle from 74° of rotation by eye is tricky
- 3 independent fits for any circle
- uses pixel values from acq / Brunson aligncam / any camera



- W1 issue
- Custom pcb's
- Prone to elec. interference
  - particularly at E2 & W2
- Very tricky to diagnose
- Single cable fault may make the whole system not work or work in odd ways
- Differences b/t scopes
- Can cascade





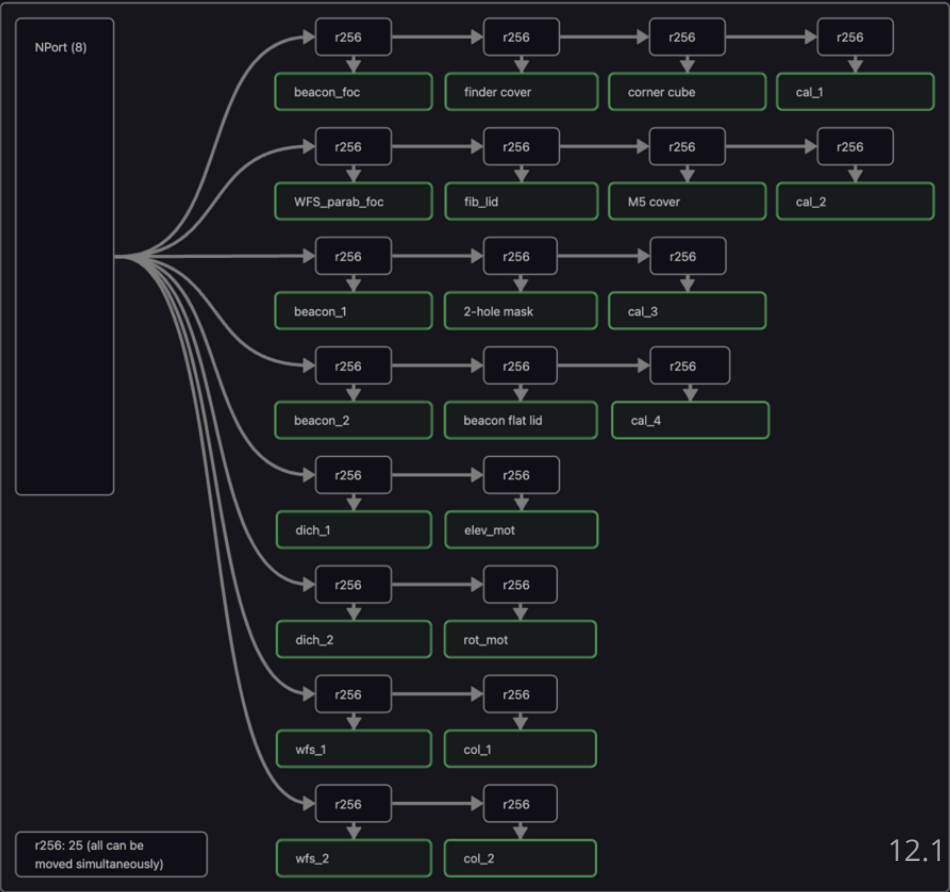
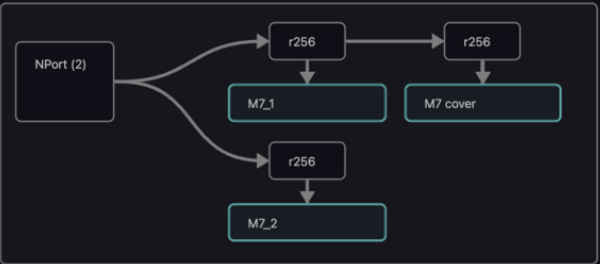


current:

- single motor driver (r256)
- multiplexed relays
- daisy chained
- sequential operation only
- little or no feedback, timing-based
- very difficult to diagnose/repair
- not necc. interchangeable

ideal:

- 1 r256 per axis
- no multiplexing
- parallel operation
- expensive (>\$10k/scope)





## aob - current



## current:

- single motor driver (r256)
- multiplexed relays
- daisy chained
- sequential operation only
- little or no feedback, timing-based
- very difficult to diagnose/repair
- not necc. interchangeable

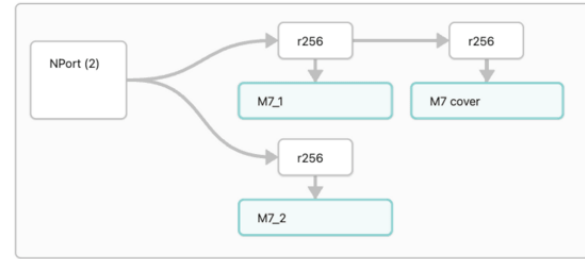
## ideal:

- 1 r256 per axis
- no multiplexing
- parallel operation
- expensive (~\$10k/scope)

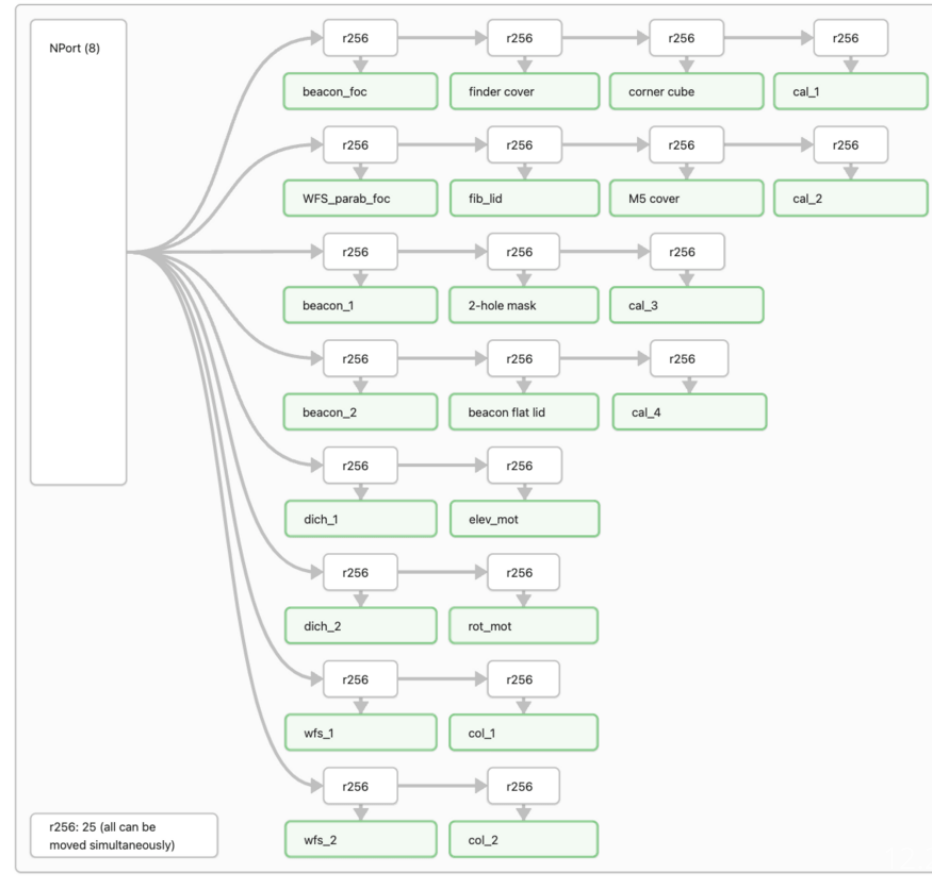
## Telescope



## Crypt



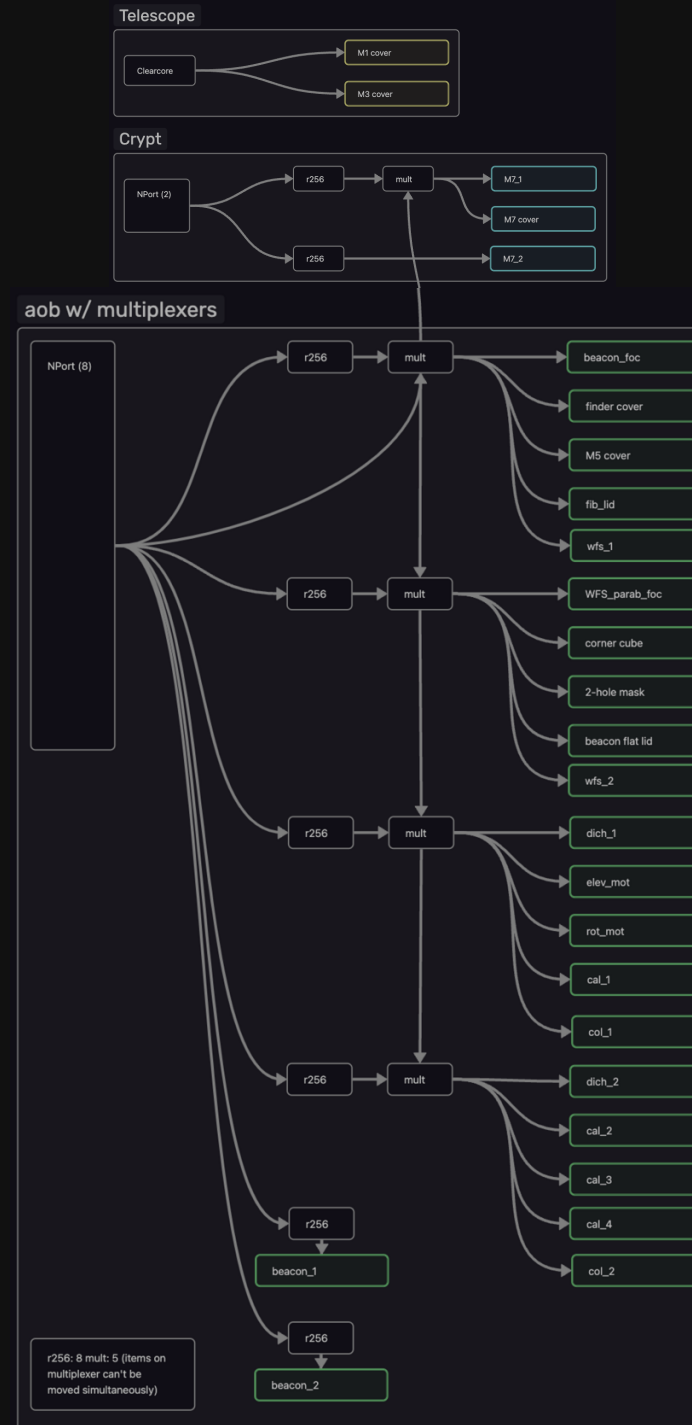
## aob - r256 per axis





## compromise:

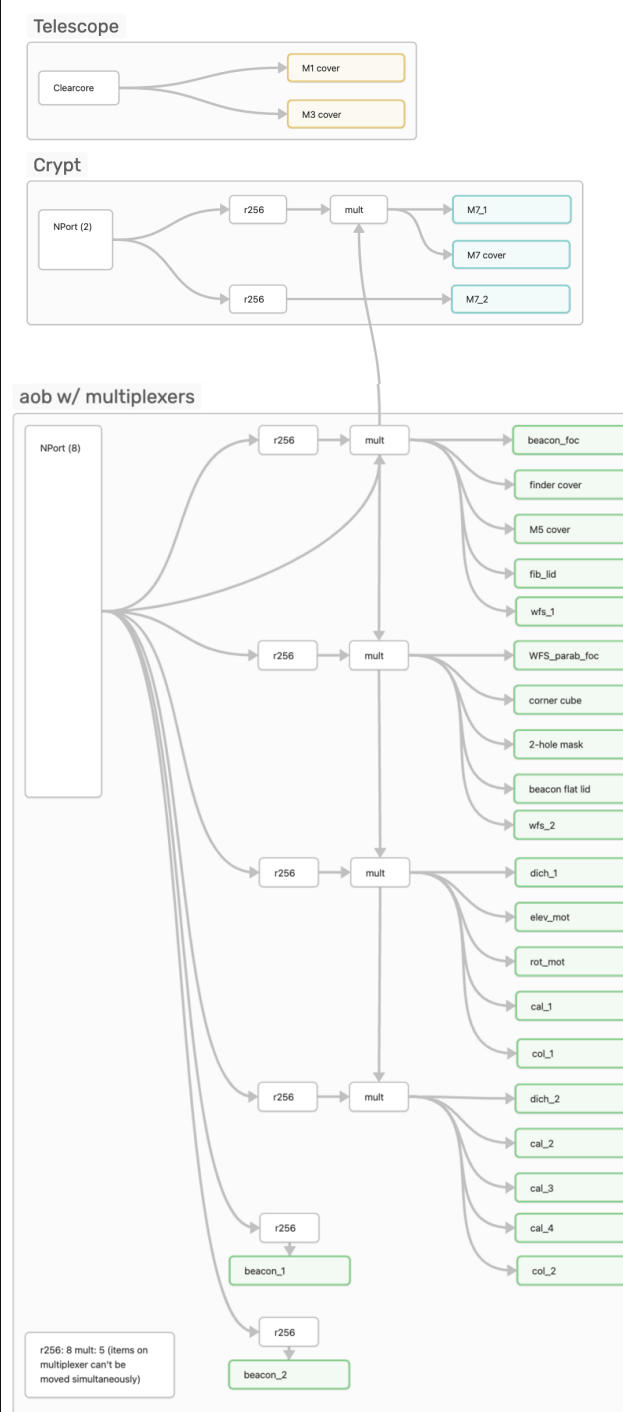
- hybrid
- replace aob control and eventually TEMA
- grouped r256's with 5 multiplexors
- only multi. those that don't need parallel operation (covers & lids)
- need to design multiplexor
- relatively easier to isolate and replace components
- expensive (~\$5k/scope)





compromise:

- hybrid
- replace aob control and eventually TEMA
- grouped r256's with 5 multiplexors
- only multi. those that don't need parallel operation (covers & lids)
- need to design multiplexor
- relatively easier to isolate and replace components
- expensive (~\$5k/scope)





- AOB/TEMA/HUT

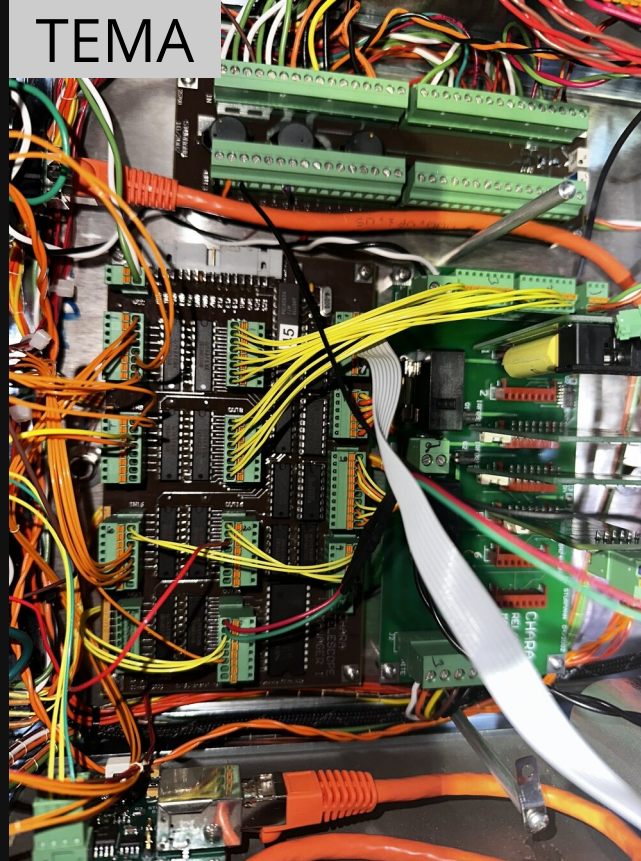
- RPC to control dehumidifiers and heaters based on minions (2/3 voting scheme)

- Cable wrap concerns

- sharp edges
  - friction welding
  - routes
  - reduced cables in wrap

- Heidenhain encoders/tape

- some show wear/damage



## Impact of SPICA and moving actuators:

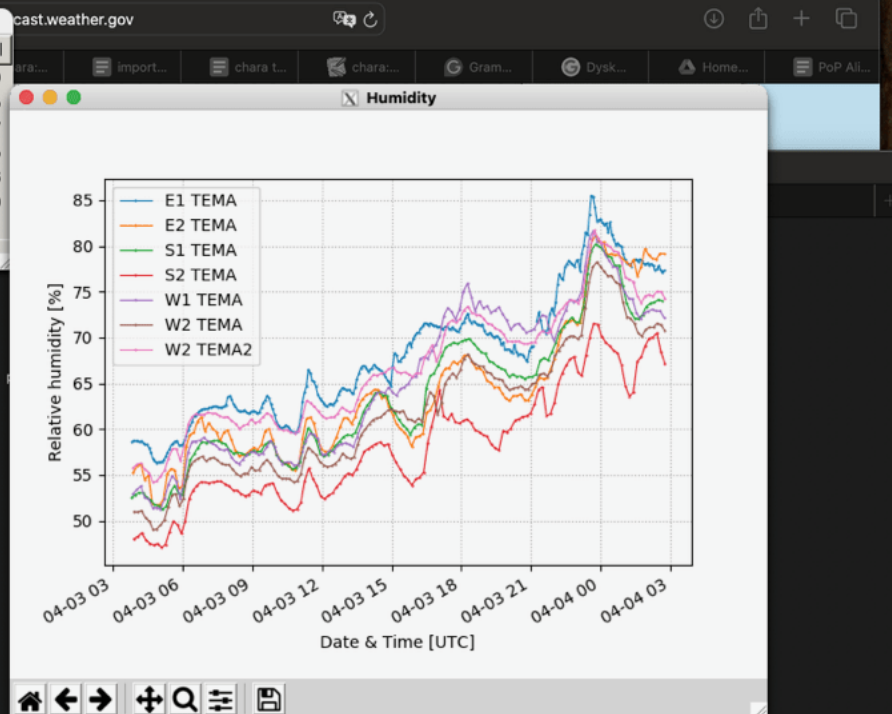
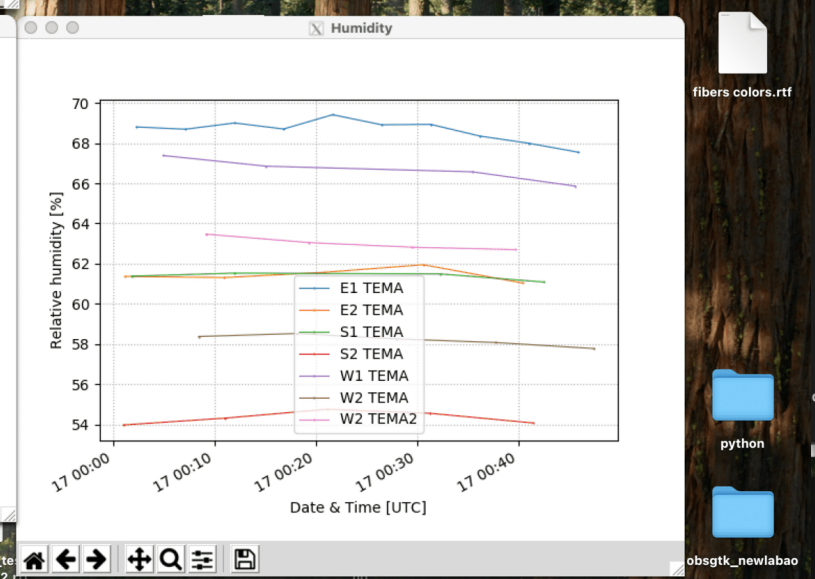
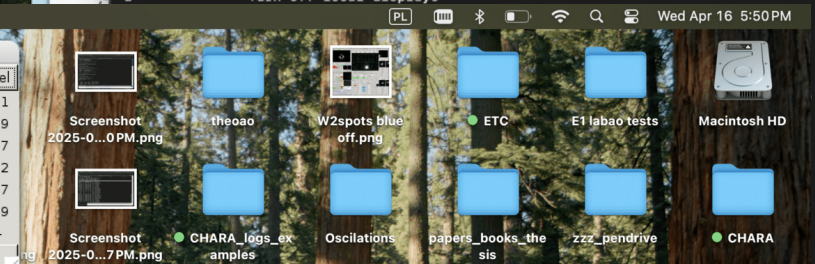
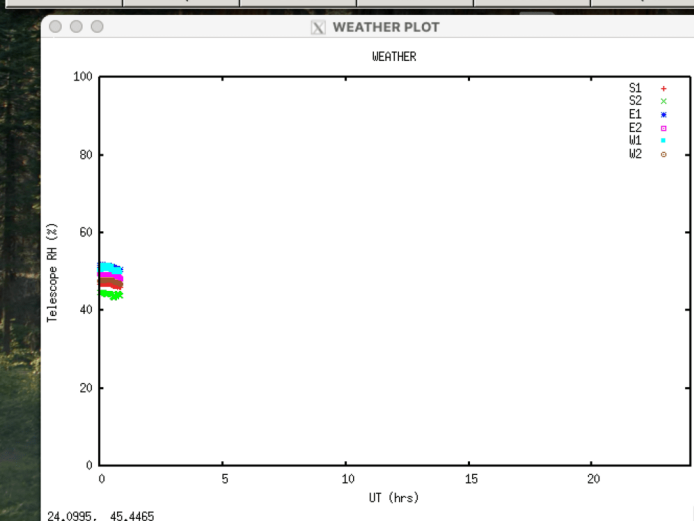
- 17 cases of beacon flat/m7 motors stuck / runout
- All required working on the motors and realigning
- All during SPICA runs or eng.
- Each was few hours of work.





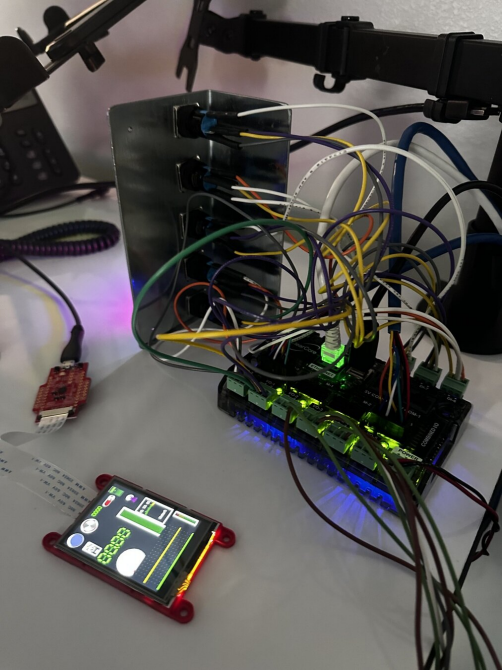
WEATHER													
SCOPE	UT	WIND	DIR	GUST	DIR	MEAN	Tout	Tbunk	RH	DP/P	Ttel	RHtel	
<input checked="" type="checkbox"/> S1	02:53	3.9	300.9 NW	9.1	282.7	2.5	1.1	7.5	100.0	1.1	8.4	52.9	
<input checked="" type="checkbox"/> S2	02:53	0.4	9.8 N	----	----	0.7	0.6	15.2	100.0	0.0	8.9	51.5	
<input checked="" type="checkbox"/> E1	02:53	0.0	286.9 W	0.0	0.0	0.0	1.1	18.4	100.0	1.1	7.6	54.7	
<input checked="" type="checkbox"/> E2	02:53	1.0	180.0 S	4.8	180.0	2.2	1.3	12.3	97.3	0.9	6.5	58.5	
<input checked="" type="checkbox"/> W1	02:53	0.0	2.8 N	7.9	337.5	0.0	1.0	14.7	100.0	1.0	7.7	53.6	
<input checked="" type="checkbox"/> W2	02:53	0.0	253.1 W	6.7	299.5	0.0	0.7	12.3	97.3	0.3	7.9	54.0	
<input checked="" type="checkbox"/> L1	02:53	0.0	180.0 S	0.0	0.0	0.0	20.1	22.5	22.7	-0.1	----	----	
NO PLOTS		AQI		DUST		PING		REOPEN		QUIT			

WEATHER													
SCOPE	UT	WIND	DIR	GUST	DIR	MEAN	Tout	Tbunk	RH	DP/P	Ttel	RHtel	
<input checked="" type="checkbox"/> S1	00:50	7.2	173.0 S	10.2	185.6	6.8	3.9	15.2	96.6	3.4	11.7	46.1	
<input checked="" type="checkbox"/> S2	00:50	6.6	168.8 S	----	----	5.2	3.5	15.2	96.0	0.0	12.4	43.9	
<input checked="" type="checkbox"/> E1	00:49	11.2	91.4 E	6.4	102.7	9.2	3.2	23.1	99.1	3.1	10.2	50.7	
<input checked="" type="checkbox"/> E2	00:49	0.0	180.0 S	8.5	180.0	0.0	4.1	14.1	94.9	3.3	11.3	48.2	
<input checked="" type="checkbox"/> W1	00:49	9.8	253.1 W	14.9	244.7	6.6	3.4	12.7	100.0	3.4	9.5	49.7	
<input checked="" type="checkbox"/> W2	00:49	0.6	105.5 E	7.7	203.9	2.4	3.6	20.6	84.1	1.2	11.2	46.9	
<input checked="" type="checkbox"/> L1	00:49	0.0	180.0 S	0.0	0.0	0.0	20.3	23.8	19.5	-0.1	----	----	
NO PLOTS		AQI		DUST		PING		REOPEN		QUIT			



Administrator to install the package 'weather-util'





- done at S2 & W1
- rest are ready
- fan control added
- same for aob



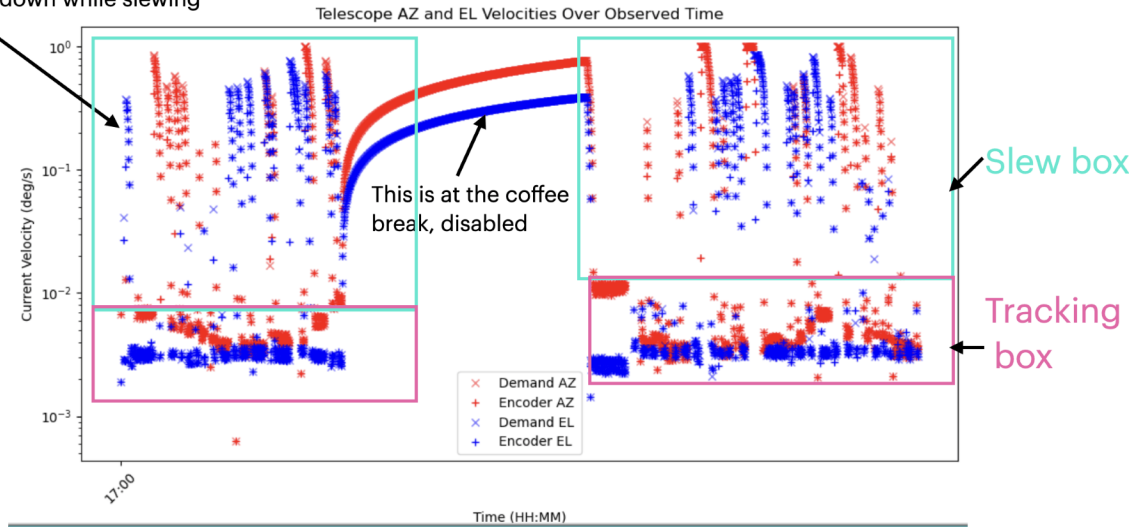


# Drive Upgrade

- S2 done and has been in use for a season, W1 after meeting
- Existing drives are ~25 years old & discontinued
- Reduce vibration, improve tuning
- Prototype assembly and short pivot arm done
- 12 drives and motors (plus spare) in hand from Parker
- Drive assemblies fabrication done (2 done, 10 remaining) - ahead of tariffs
- Spare Dojen obtained
- Install during daytime, but some nights needed for software and tuning

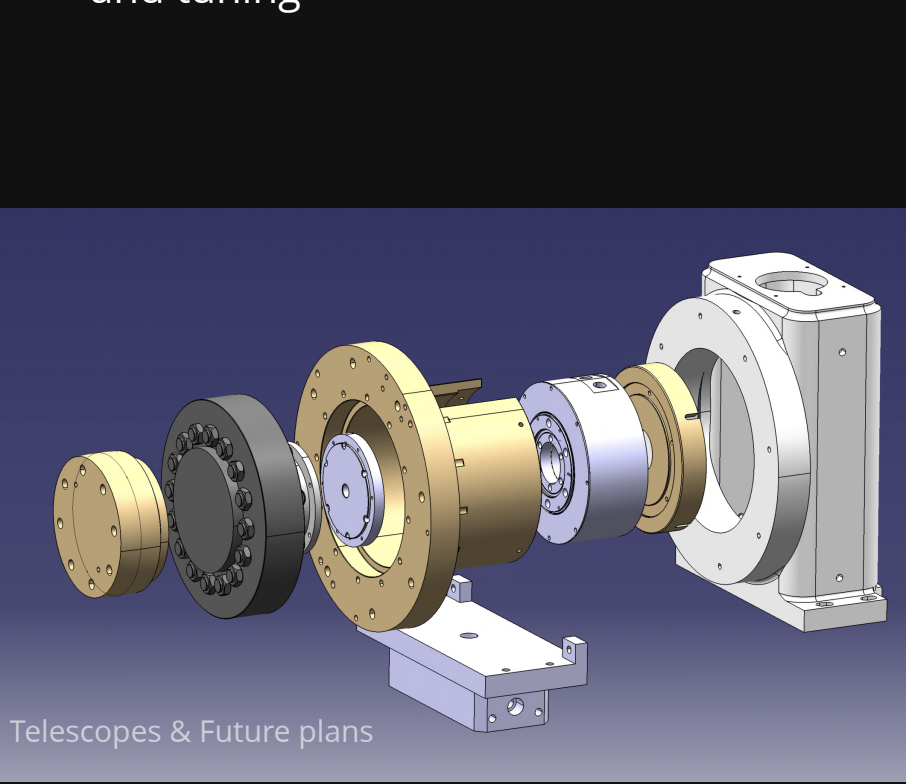
Encoder velocity

ramped down while slewing

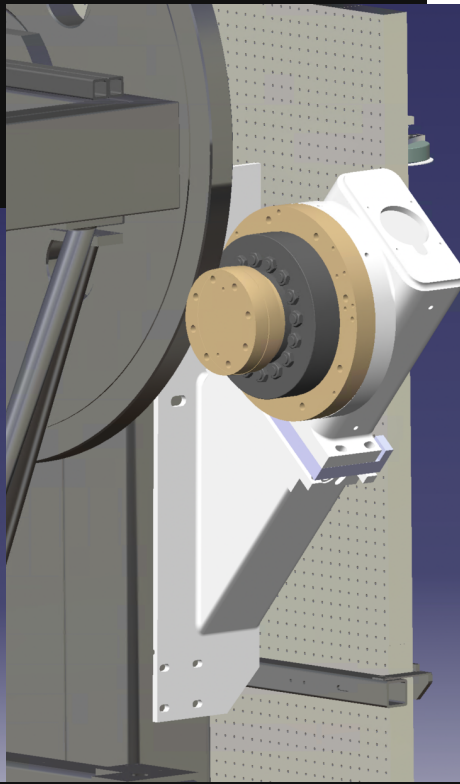


Each column is a star slew

The elevation tracking is better than azimuth



Telescopes & Future plans



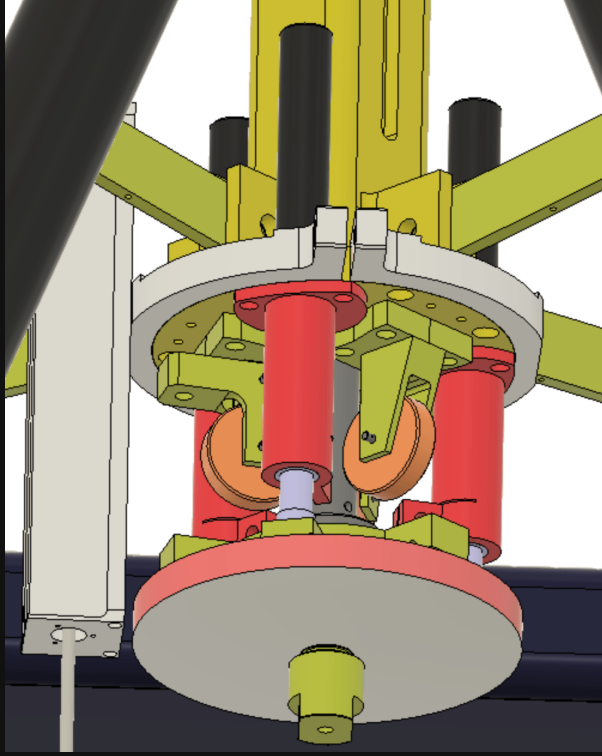
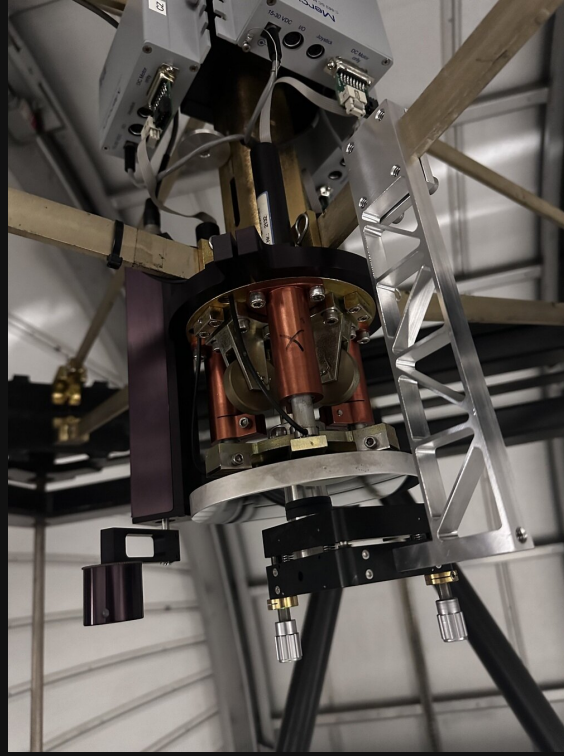




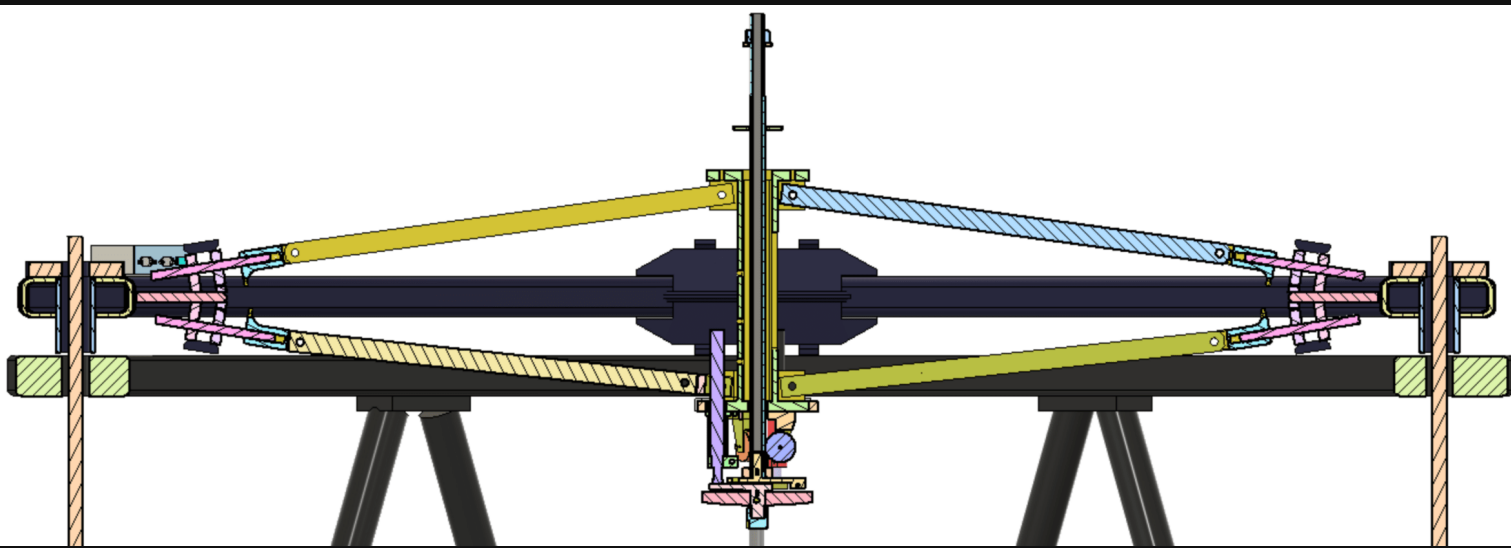


# Tiptilt, PZT issues, actuators, hexapods?

- Tiptilt concerns
  - PI PZT's discontinued in 2018, could be sent for repair but limited
  - use DM for TT correction (but can't do on-sky reconstructor in this case)
  - actuators were discontinued in 1992
  - replace PI PZT's with Thorlabs PZT's or newer PI actuators+PZT
  - get one hexapod (~\$50k) and then we have spare parts for rest of array



- 11cm: spider → back of M2
- adjusting spider could get few more cm
- M2, d=140mm
- may need a piezo tiptilt system b/t hexapod and M2, but depends
- needs to function hanging upside down



New fiber network (new IP pool)

new spycam system (3 per telescope up to 4k+audio, 3 w/ pan/tilt in lab), more sensors (rh, temp) and control

The screenshot displays a web-based telescope control interface. On the left is a sidebar with an 'Organizations' tree. The main area shows a live video feed of the telescope's mechanical structure, labeled 'S2' in the bottom left corner. The video feed has a timestamp '2024-03-12 11:35:22' in the top right. Overlaid on the video are two control panels. The top panel is a terminal window titled 'cool-retro-term' showing a shell prompt and directory listing. The bottom panel is a 'DOME S2' control window with tabs for 'MESSAGES', 'DOME', 'MANUAL', 'AUTO', 'RA/DEC', 'PLANETS', 'TUNE', and 'CPUMON'. It contains a table of telescope parameters and a set of control buttons.

**Organizations**

- Search...
- Default Group
  - 192.168.60.122
  - 192.168.60.131
  - 192.168.60.132
  - 192.168.60.146
  - PC-NVR
- lab
  - lab2
  - lab3
- SPICA
- office
  - lab1
- telescopes
  - S2

**Terminal (cool-retro-term)**

```
(s2:510) cd control
(s2:511) ls
CHAMP Makefile astropci-xeno doc example
CVS WindRiver ccd dos522 header.c
MIRC astropci-rtai cliserv etc header.mk
(s2:512) run_power
run_power: command not found
(s2:513) rpc_gtk
rpc_gtk: command not found
(s2:514) rpc
rpc_basic_gui rpcgen rpc.idmapd
rpc_basic_gui~ rpc.gssd rpcinfo
rpcbind rpcgtk rpc_server
rpc_client rpcgtk_20190403 rpc_server_2
rpcdebug rpcgtk_zmq rpc_server_e
(s2:514) rpc_basic_gui &
[4] 19585
(s2:515)
```

**DOME S2**

MESSAGES | DOME | MANUAL | AUTO | RA/DEC | PLANETS | TUNE | CPUMON

Az: SLEWING - CHARA Time: 18:35:24			El: SLEWING - SIDERIA
Az: 135.3169	Az Vel: 0.0000	Er: -0.0000	El: 83.3003
Dm: 135.3169	Mode: MANUAL	Dec: 29 12 55.12	Dm: 87.4270
Ra: 22 27 17.518	Dem: 61 45 03.73		
Dm: 11 03 43.671			

SERVO OFF	REOPEN DRVS	LIGHT ON	DISABLE
STOW	PING	LIGHT OFF	ENABLE



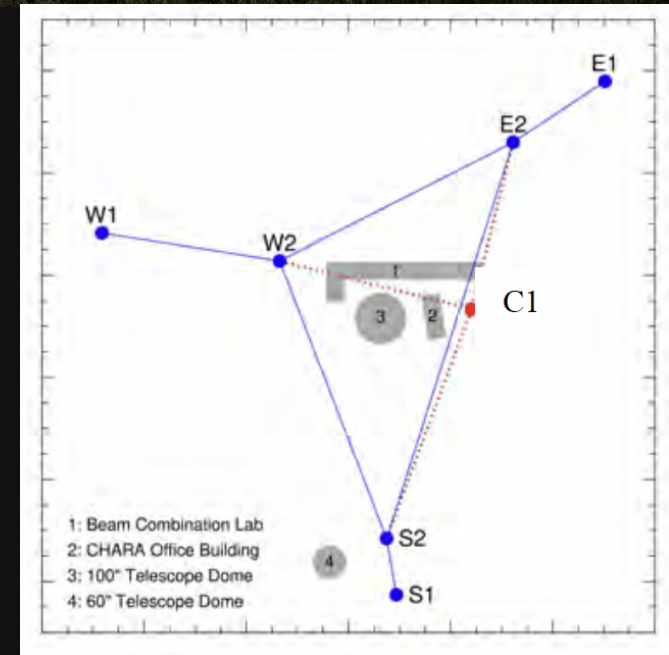
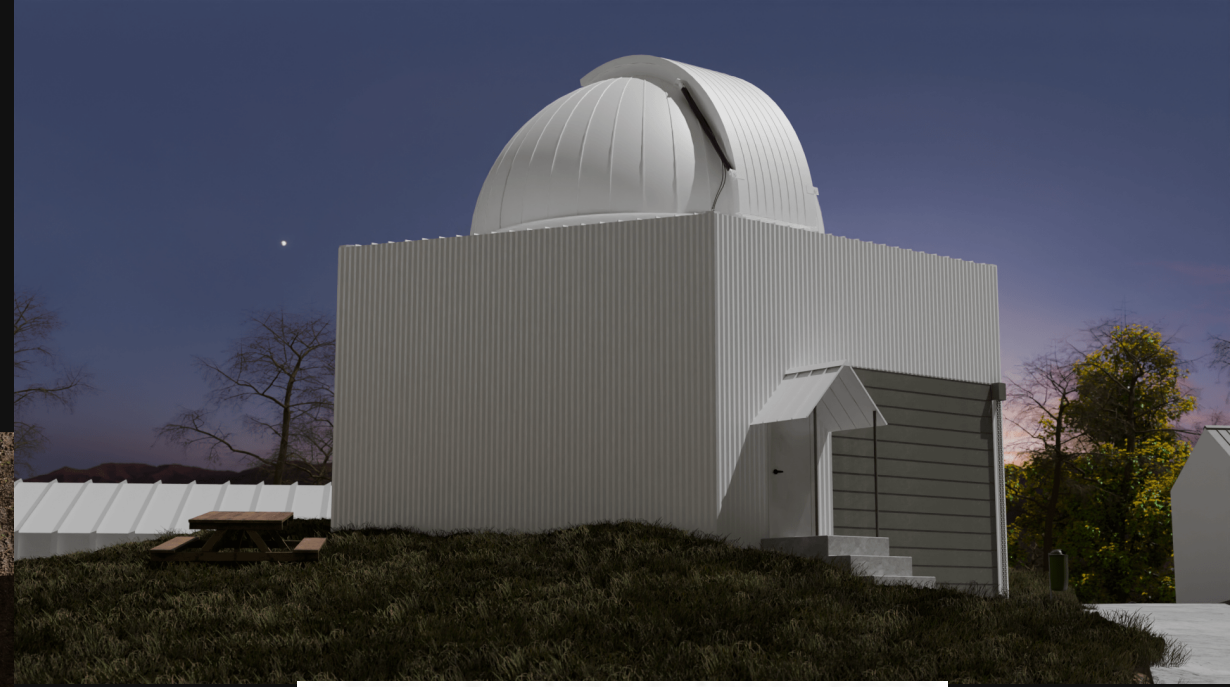
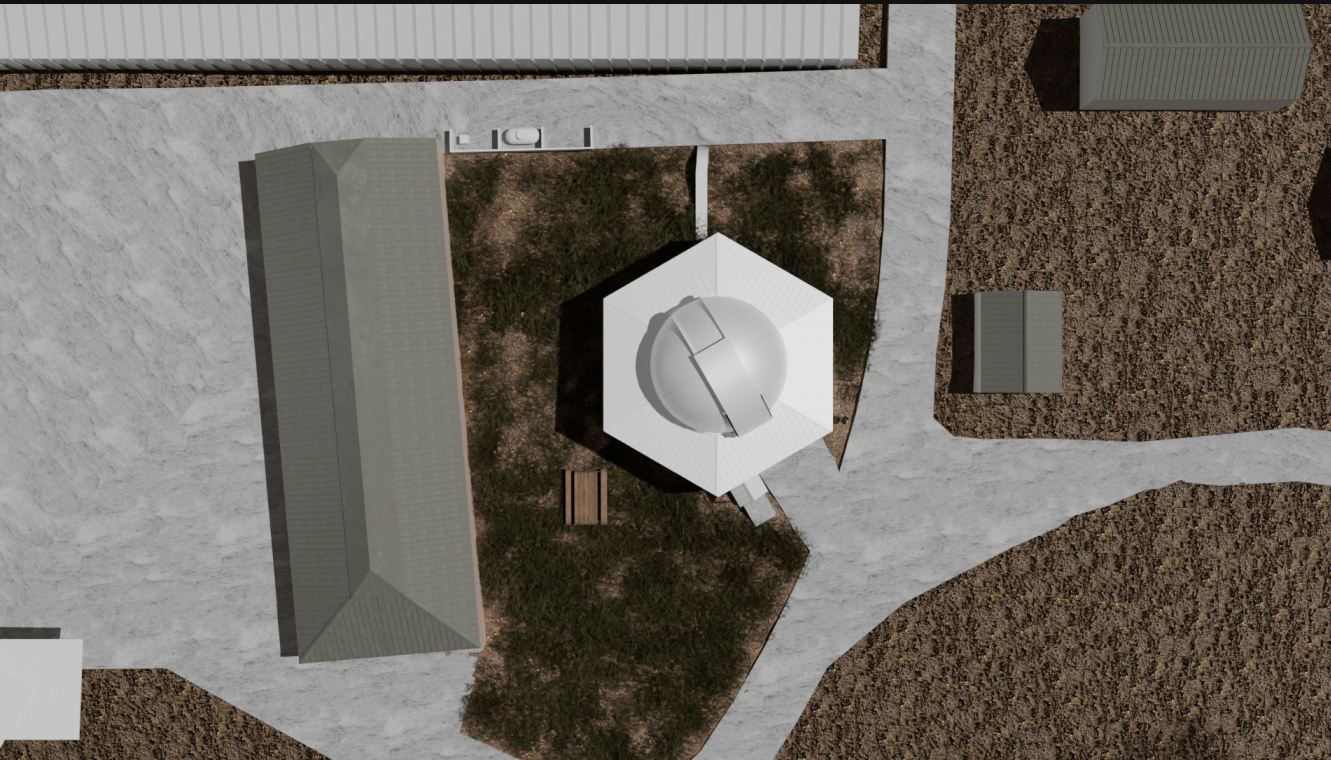
# Plan Outline:

(2024 Meeting on CHARA Future)

- **Phase 0:** AC at telescopes
- **Phase 0.1:** new IR dichroics for beam samplers
  - Improve multi-wavelength performance
  - Wider bandwidth for better STST performance
    - CRED1, bluer for science, WFS on a single chip?
  - Dual-star phase reference mode
- **Phase 0.5:** upgrades of telAO
  - Redesign M2, go to focal design?
- **Phase 1:** central 2m + AO + OPLE upgrades
  - LabWFS control new telDM,
  - Longer delay + better metrology or double-decker carts
    - Visible-sensitivity, resolution, stability → needed for nulling
- **Phase 2:** replace 1m's with 2m's
  - Propagate upgrades from central 2m
- **Phase 3:** full CMA - outer km baseline fiber array

# Central 2m Telescope

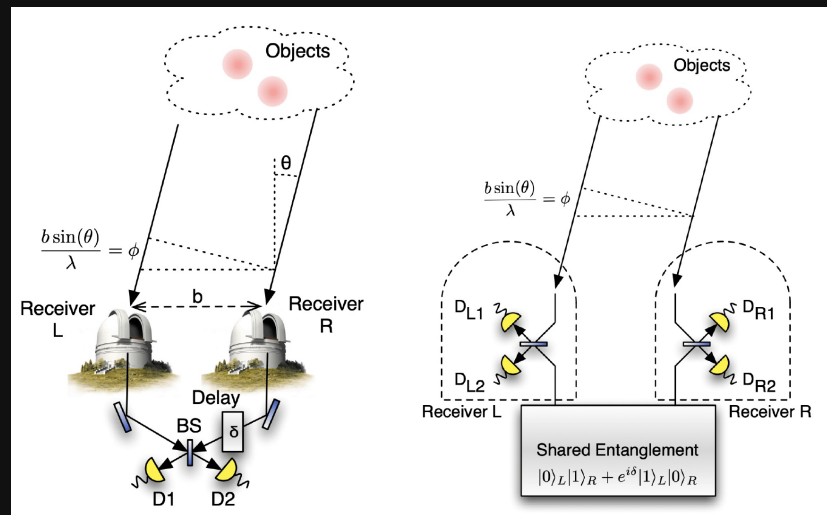
- Vacuum beam transport with fiber option
- Bundled with Delay Line Upgrades





- Review the current state of capabilities & techniques in optical/IR interferometry
- Discuss quantum-enhanced methods for pushing current limitations on spatial resolution
- Establish collaborations between the astronomy & quantum communities to address science requirements and technical challenges

*"Performance of the Khabiboulline Configuration of Quantum Enhanced Long Baseline Optical Interferometry"- McClinton & Ridgeway (AAS 2025)*



open-air or quantum-enhanced  
future beam transport?

**Initial HBT experiments planned this yr with BNL**

*"Towards quantum-enhanced long-baseline optical/near-IR interferometry"*

Rajagopal et al. (2024)

*"Towards Quantum Telescopes: Demonstration of a Two-Photon*

*Interferometer for Quantum-Assisted Astronomy" - Crawford et al. (2023)*

# Charting Quantum Horizons:

ESTABLISHING A ROADMAP FOR MICROARCSECOND ASTRONOMY

11 March 2024 Tucson Arizona

**Scientific Organizing Committee**

Ryan Lau (NSF's NOIRLab, Astro Co-Chair)  
Amit Ashok (University of Arizona, Quantum Co-Chair)  
Douglas Gies (Georgia State University / CHARA)  
Sankar Guha (University of Arizona)  
John Monnier (University of Michigan)  
Joel Sánchez Bermúdez (National Autonomous University of Mexico)  
Gail Schaefer (Georgia State University / CHARA)  
Brian Smith (University of Oregon)  
Aziza Suleymanzade (Harvard)

**Local Organizing Committee**

Julie Emery (University of Arizona / Center for Quantum Networks)  
Jessica Harris (NSF's NOIRLab)  
Zachary Hartman (International Gemini Observatory/NSF's NOIRLab)  
Lynn Lau (University of Arizona / Arizona Quantum Initiative)  
Brittany McClinton (NSF's NOIRLab)  
Nick Padilla (University of Arizona)  
Jayadev Rajagopal (NSF's NOIRLab)  
Gabe Richardson (University of Arizona)  
Stephen Ridgway (NSF's NOIRLab)

[noirlab.edu/science/events/websites/astro-quantum-interferometry-workshop-2024/](https://noirlab.edu/science/events/websites/astro-quantum-interferometry-workshop-2024/)

Logos: NSF, NOIR Lab, AURA, CHARA, Arizona Quantum Initiative, Center for Quantum Networks



# Risks:

very uncertain US environment

Funding options:

- NSF (66% cut proposed)
- private: Heising-Simons Foundation, Keck, Kavli Institute, others
- extend the consortium?
- other universities?
- National lab status?
- International partnerships?









# CHARA in 2040

## (near future plans)

- Telescope dichroic upgrade
- Automated alignment/tracking
- Upgrade labAO system
- Optimizing multi-wavelength simultaneous observations
- Fibers to all telescopes
- W5 site (1100m)
  - extended/double-pass delay
- Up to 300 nights over three years of open access time via NOIRLab.

## (bigger future plans)

- Central 2m telescope
- 1m's → 2m's
- Km+ baselines
- AO/optic/lab upgrades
- Off-target phase tracking
- Nuller
- Future beam transport
- Michelson Array

