LAVA a new LGSF concept for the W.M. Keck Observatory

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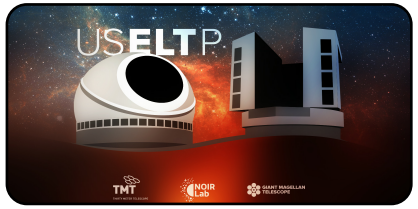
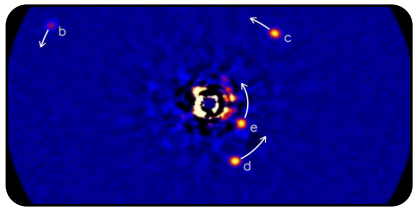
Workshop of Laser Technology and Systems for Adaptive Optics– June, 2023

Why a new LGSF?

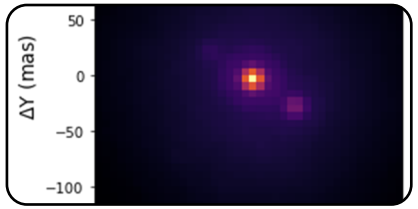
AO in Astro2020 Report



#1: “large (20-40 m) telescopes with diffraction-limited adaptive optics”

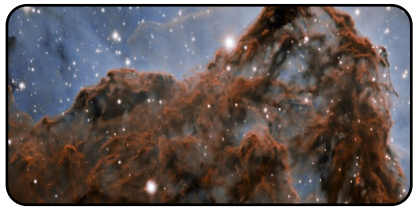


“Key capabilities required on the pathway to habitable worlds include the following: Ground-based extremely large telescopes equipped with high-resolution spectroscopy, high performance adaptive optics, and high contrast imaging”



Foundational Activities: “Expand support for early-stage and basic technology development” through APRA and ATI.

- “including the pressing need to develop advanced adaptive optics systems in the optical”



“Wide-field AO (GLAO, MCAO, MOAO, LTAO) delivers uniform wavefront correction over large areas, achieved by sensing the atmospheric turbulence profile with multiple laser beams assisted with natural guide stars, and serving a very wide range of areas from Galactic to extragalactic science.”

WMKO 2035 Science Strategic Plan

The Scientific Strategic Goals

Strategic Goal	Description
1	Continue to support a broad OIR science portfolio with a diverse set of highly sensitive imaging, spectroscopy, and high spatial resolution capabilities
2	Enhance the WMKO community's competitive advantages in cadence, time domain, and large sample programs for precision spectroscopy, astrometry, and photometry
3	Sharpen our view of the universe with near diffraction-limited capabilities at visible wavelengths
4	Make maximal use of the unique capabilities of the Maunakea observing site including excellent seeing, UV sensitivity, and northern hemisphere access
5	Provide cutting edge science opportunities to the Keck community by hosting technology demonstrations for ELTs and space missions
6	Increase science yield with improved efficiency from instrument upgrades, state of the art seeing management, innovative operations improvements, excellent instrument calibration and characterization, and data reduction pipelines

Large Scale Projects > $15M

Priority	Name	Strategic Goal Mapping
A	Keck 1 ASM for GLAO & Visible MCAO	1,2,3,4,5,6
	Liger	1,2,3
B	FOBOS	1,2,4
	GLAO on K1 for LRIS & MOSFIRE	1,2,4
	KWFI	1,2,4
	Visible AO on K1	1,3,4,5
C	GLAO on K2	1,3,4
	K2 ASM	1,4,5,6
	Visible AO IFU for K1	1,3,4

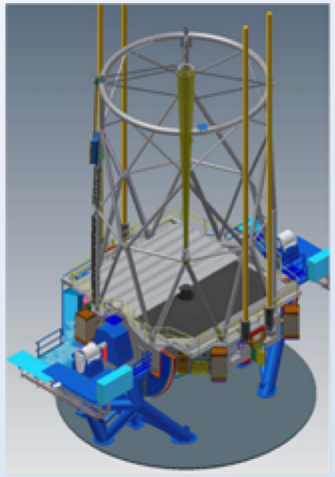
Medium Scale Projects $5M - $15M

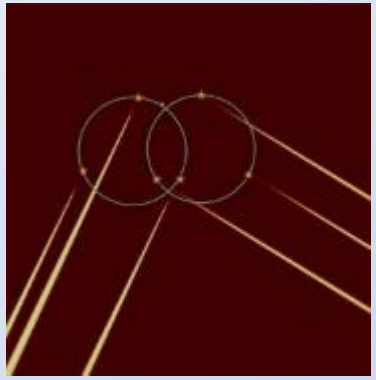
Priority	Name	Strategic Goal Mapping
A	HISPEC	1,2,3,4,5
	Instrumentation Development Fund	1,2,3,4,6
	LRIS2	1,2,4
B	Visible AO imager	1,3,4

Small Scale Projects < $5M

Priority	Name	Strategic Goal Mapping
A	AO Development Fund	1,3,4,5,6
	DEIMOS+	1,2,6
	HAKA	1,3,4,5
	KPF K2 FIU	1,2,4,5
B	High Contrast Technology Development	1,5
	MOSFIRE + GLAO	1,2,4,6

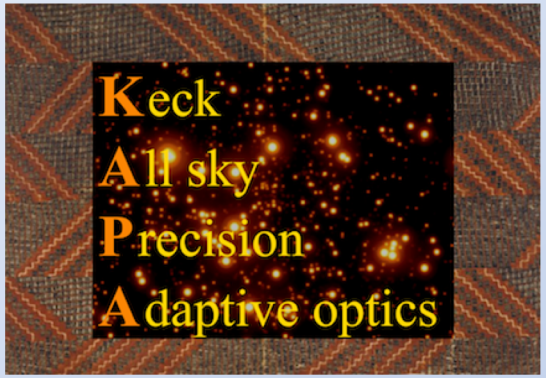
Wide Field AO at 8-10 meters

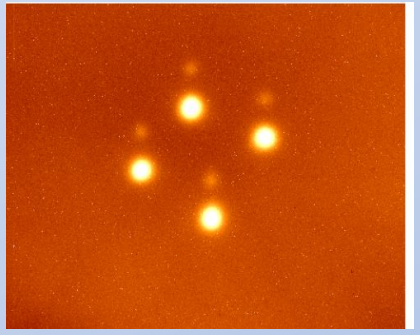




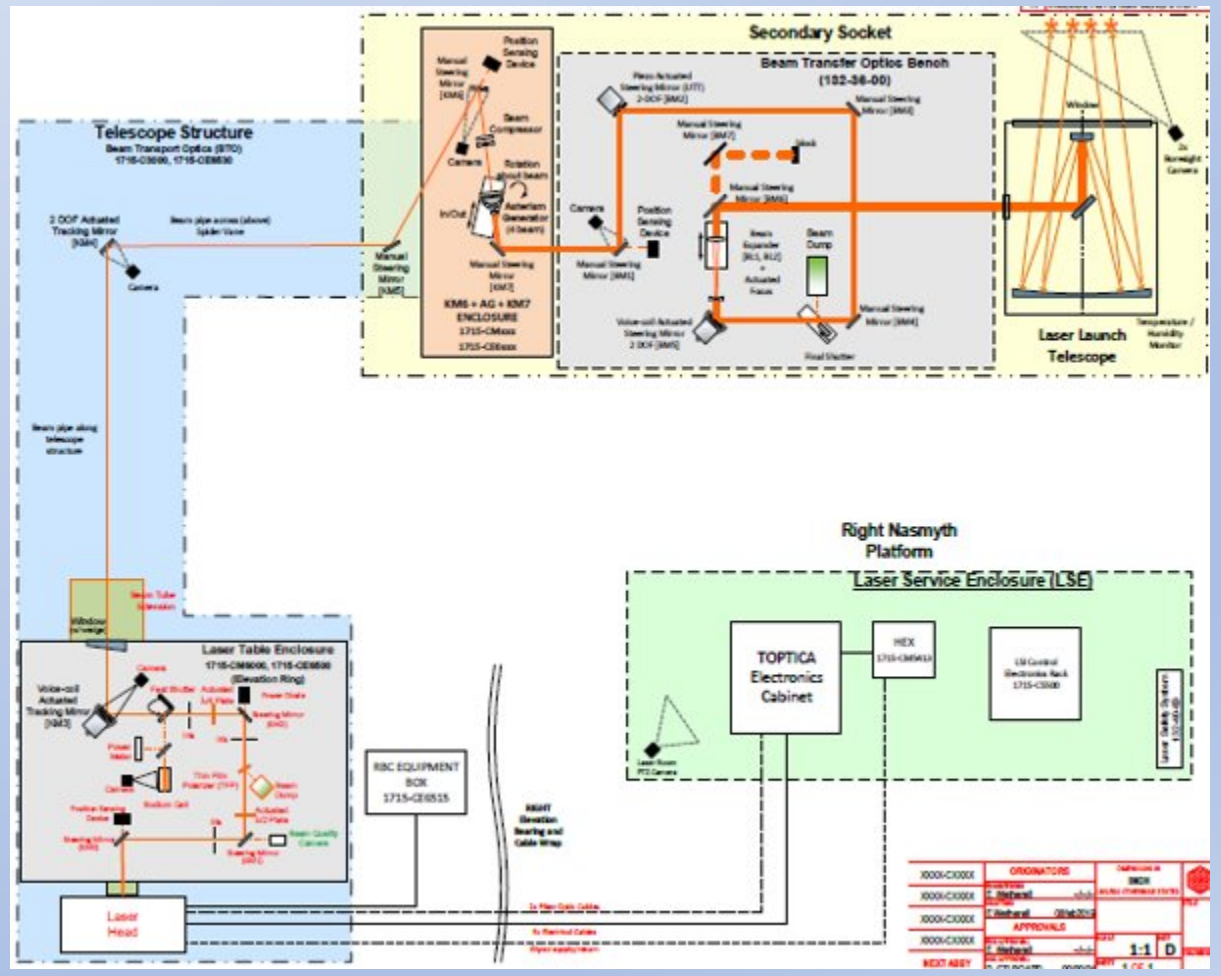
Instrument	FoV	Type
MUSE + GALACSI	1’x1’	GLAO
GeMS	2’	MCAO
ARGOS	4’x4’	GLAO
Hawk-I + Graal	7.5’x7.5’	GLAO
GNAO	2’	GLAO
MOSFIRE + Keck GLAO	6’x6’	GLAO
LRIS-2 + Keck GLAO	5’x10’	GLAO
ULTIMATE-Subaru	14’x14’	GLAO

Current K1 LGSF



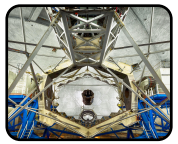


- Center launch system to support single laser guide star operations and 4 laser guide star operations for LTAO
- Splits one 22W Toptica laser into 4 equal power beams
- Designed for small asterism radius of 7.6”
- Full pointing range of 60”
- Insufficient for wide field GLAO



LAVA

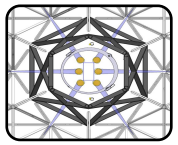
Laser Atmospheric Volumetric Array



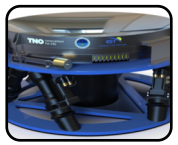
A new LGSF proposed for the K1 telescope

Supports GLAO with the possibility of supporting current and future AO as well

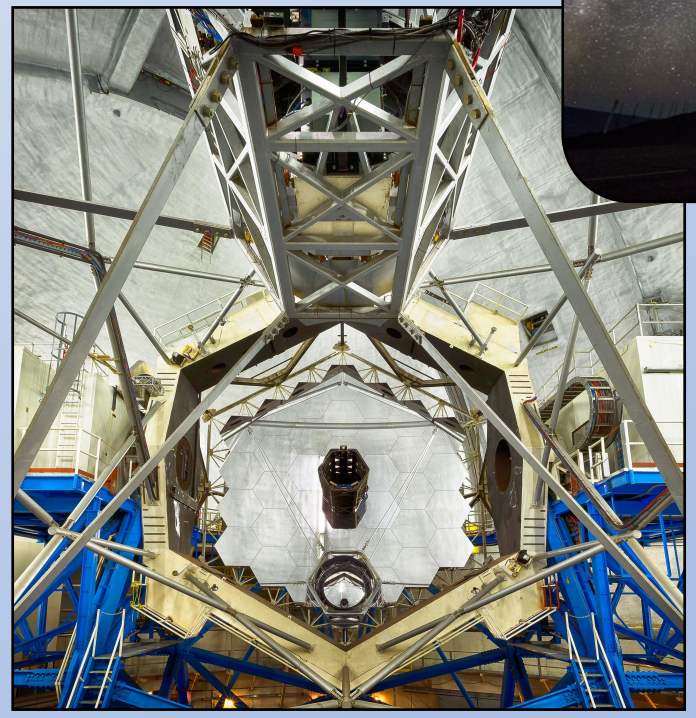
Multiple side launched LGS beacons



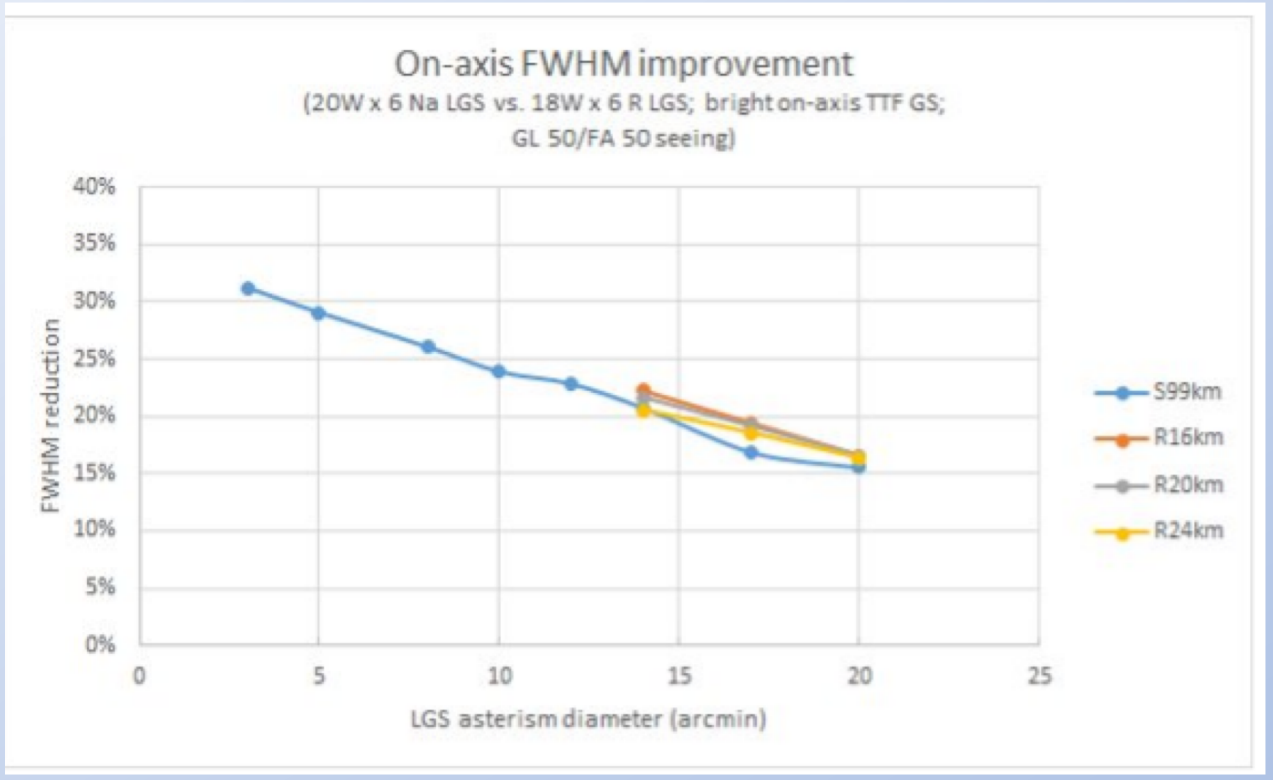
GLAO WFSs located in the telescope Cassegrain tower to support Cass instruments

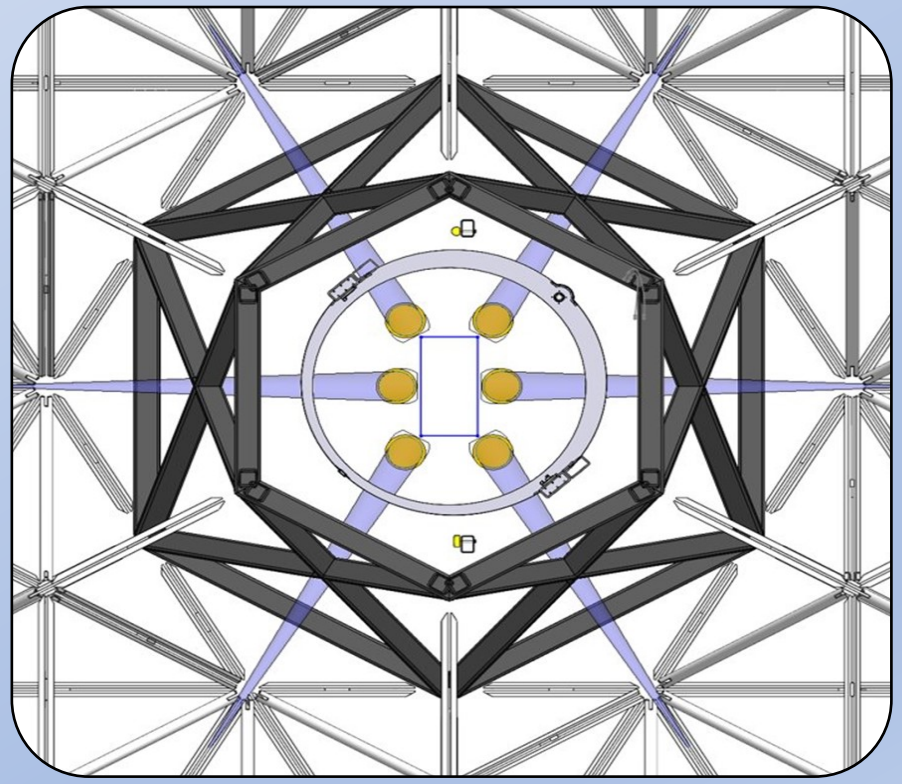


Compatible with ASM



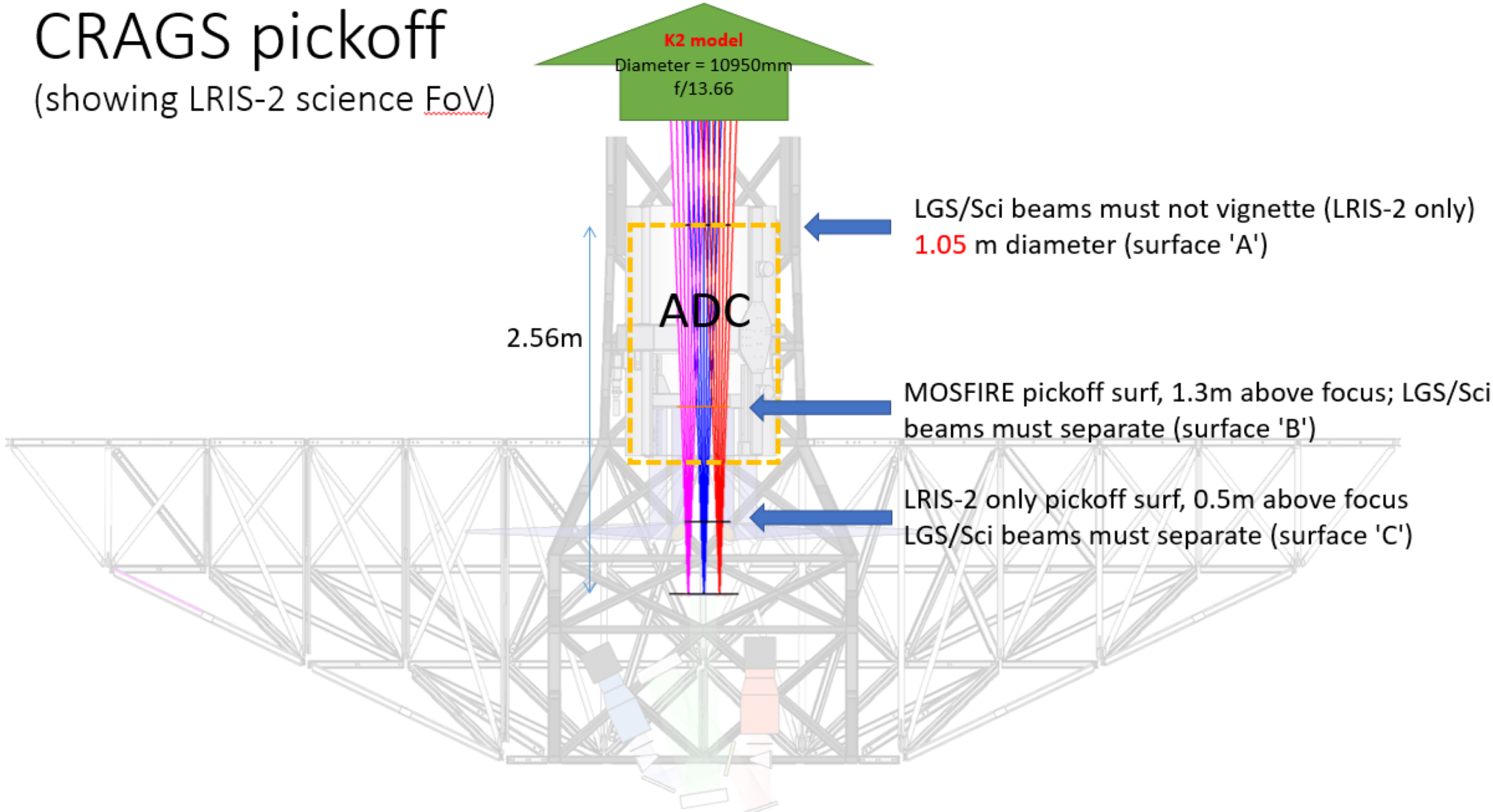
Technical constraints to asterism diameter



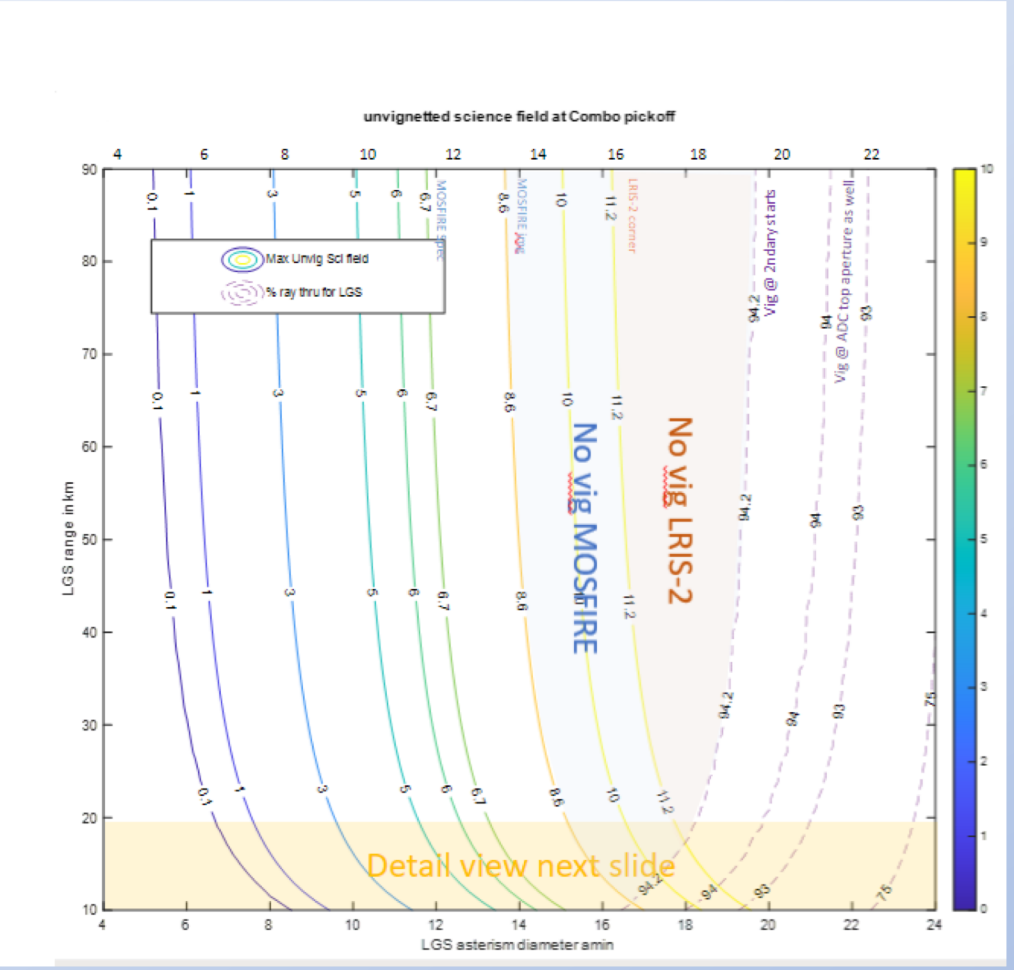


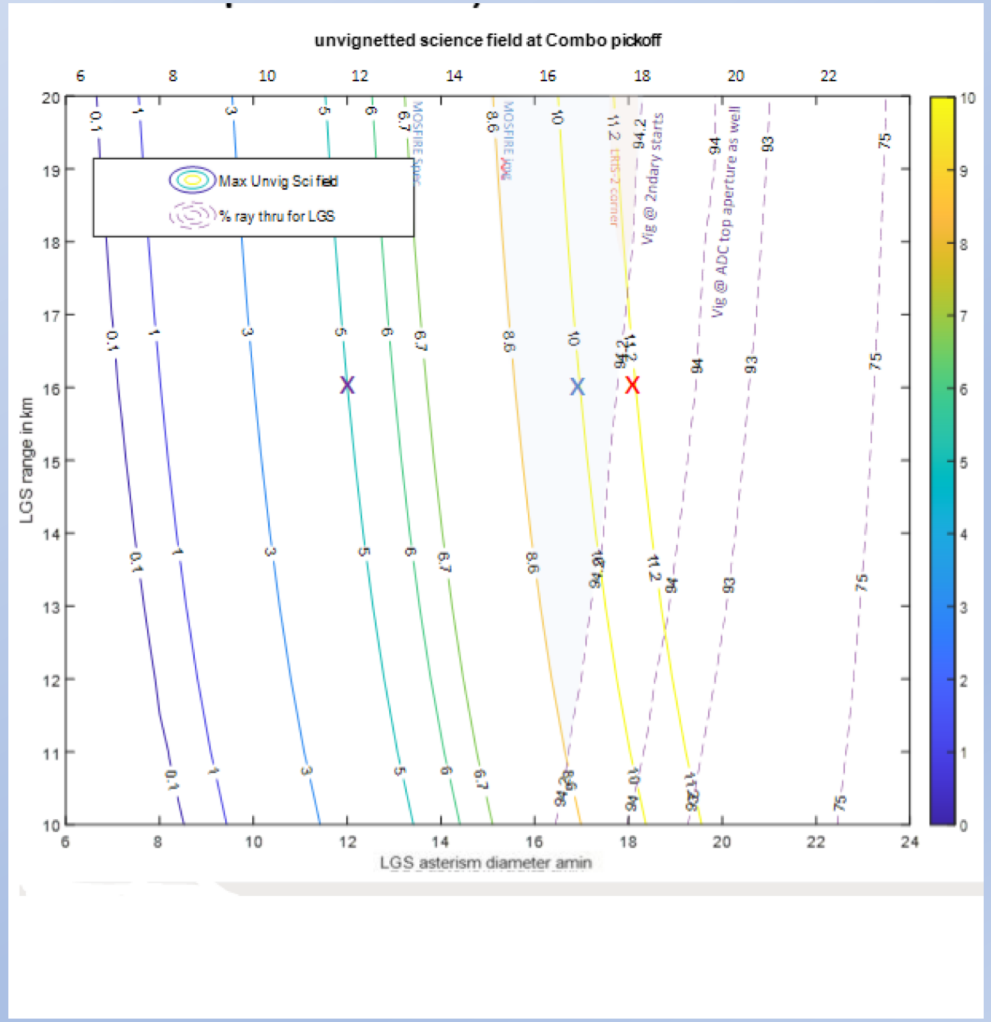
CRAGS pickoff

(showing LRIS-2 science FoV)



Unvignetted FoV





Min asterism diameter with no vignetting

If your science FoV is 3', then your asterism can be as small as 10' in diameter

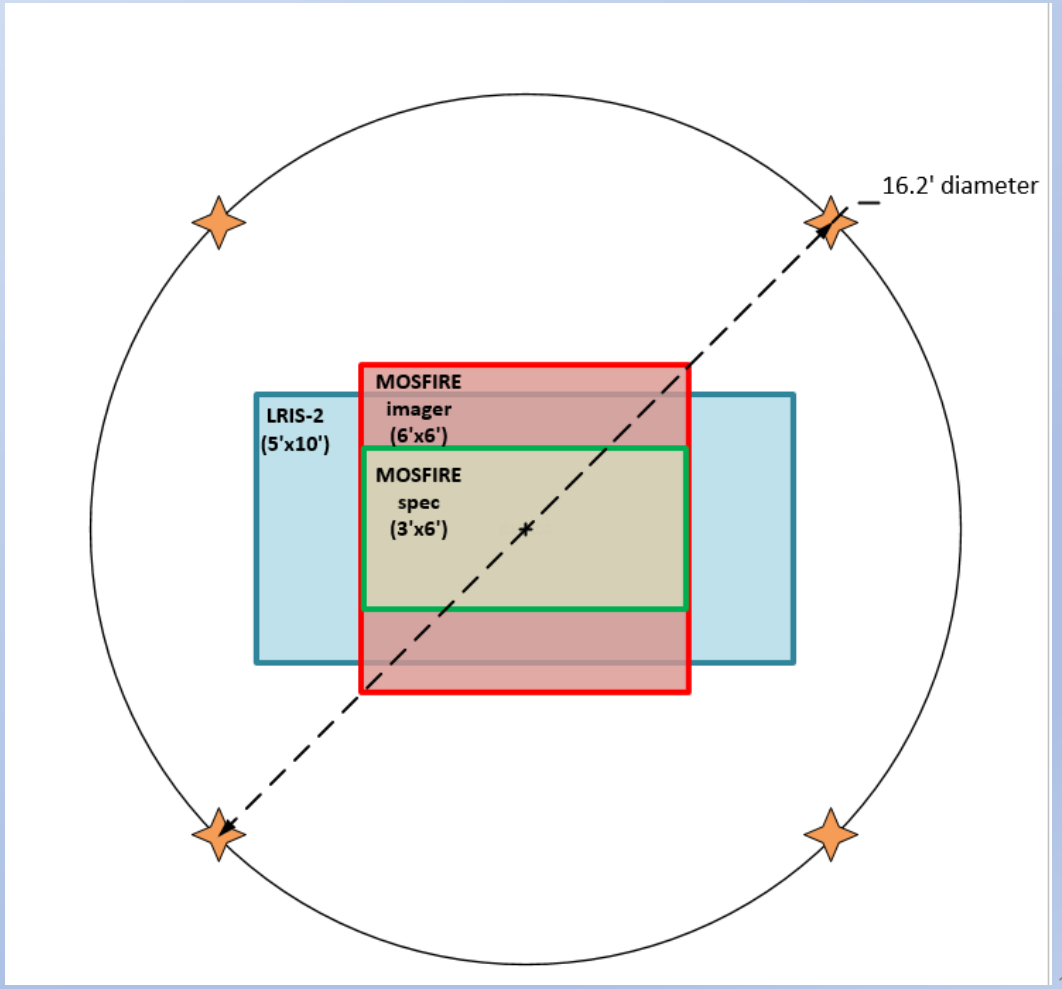
# pick off mirror sets		Na asterism			Rayleigh (16km) asterism		
2 (@ B & C)	General asterism diameter	Sci + 5' (MOSFIRE pickoff@B) Sci + 2.2' (LRIS-2 pickoff@C)			Sci + 7' (MOSFIRE pickoff@B) Sci + 4' (LRIS-2 pickoff@C)		
	Instrument	LRIS-2	MOSFIRE (Img)	MOSFIRE (Spec)	LRIS-2	MOSFIRE (Img)	MOSFIRE (Spec)
	Asterism diameter which allows the whole instrument FoV unvignetted	13.4'	13.6'	11.7'	15.2'	15.6'	13.7'

LAVA Requirements

L1 #	Level 1 System Requirement
1	System shall generate 4+ laser guide stars producing an SNR on WFS of XX (TBD)
2	System shall generate a variable LGS asterism of up to 16.2' in diameter
3	System shall be side launched
4	System shall be reconfigurable between 1-4+ LGS
5	Asterism shall be movable during science observation
6	System shall be used with an ASM as the deformable mirror for GLAO
7	System shall be compatible with Cassegrain mounted WFSs
8	Total weight added to elevation ring shall not exceed 5000 KG (TBC)
9	System shall be mounted without interfering with future instruments in bent cass ports (volume TBD)
10	System shall limit laser and laser scatter contamination

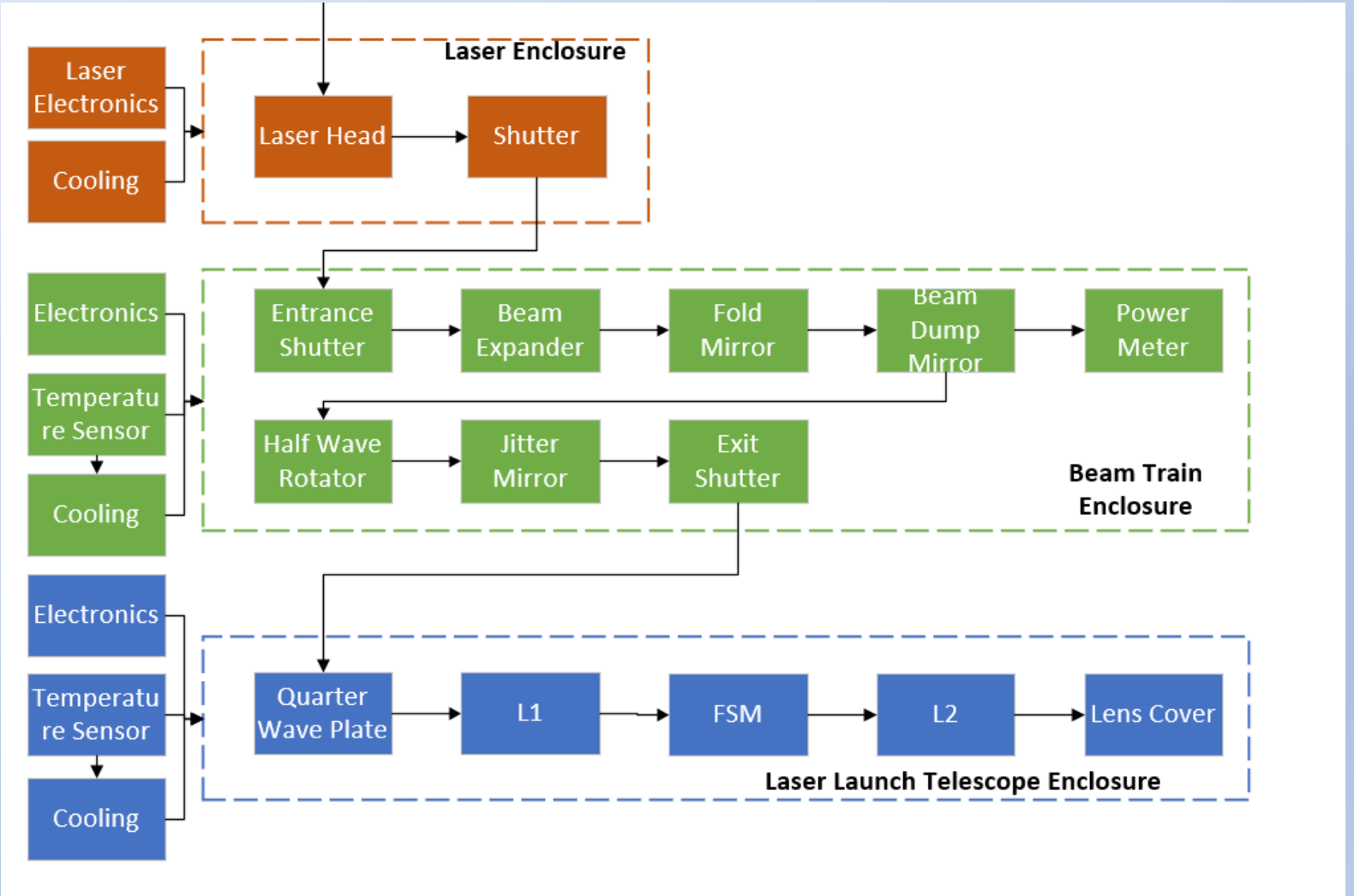
LAVA concept

- Minimum of 4 laser guide stars launched from elevation ring
- Open to Na, Rayleigh, or combination of the two
- One LGS per projector
- Use of commercial products where available
- Potential for future use by other flavors of AO



Individual projectors units

- Each unit provides one laser beacon
- Open to different laser technologies
- Each unit mounted on telescope elevation ring



What's out there?

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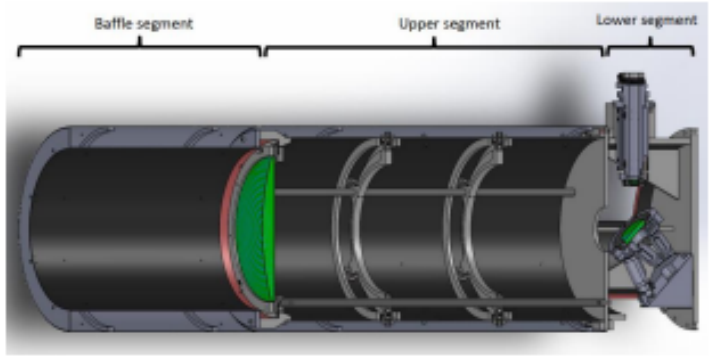
MECHANICAL DESIGN

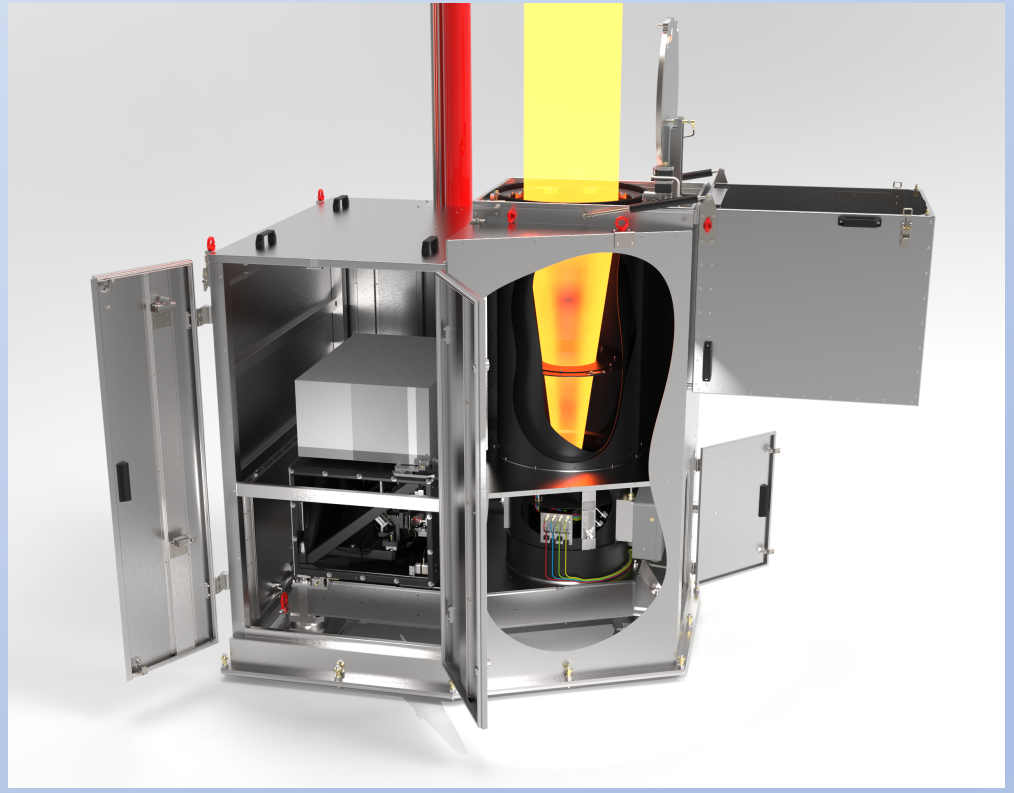
LLT can be subdivided into:

- Lower segment (L1 + FSM)
- Upper segment (L2)
- Baffle & thermal shield

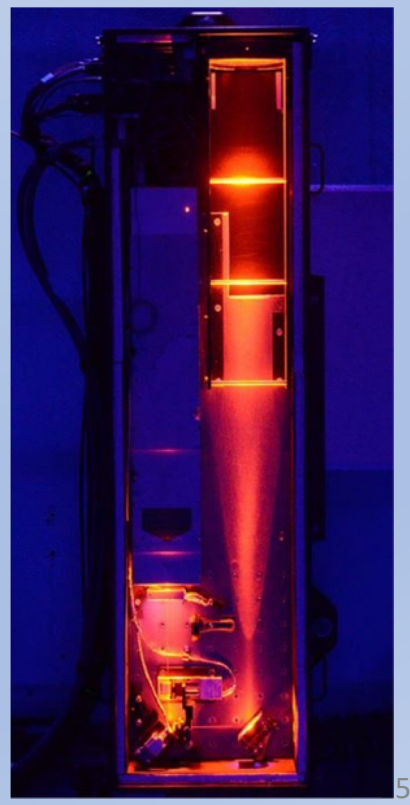
In order to avoid any focus correction during the observative night, an athermal design has been accomplished.



TNO innovation for life

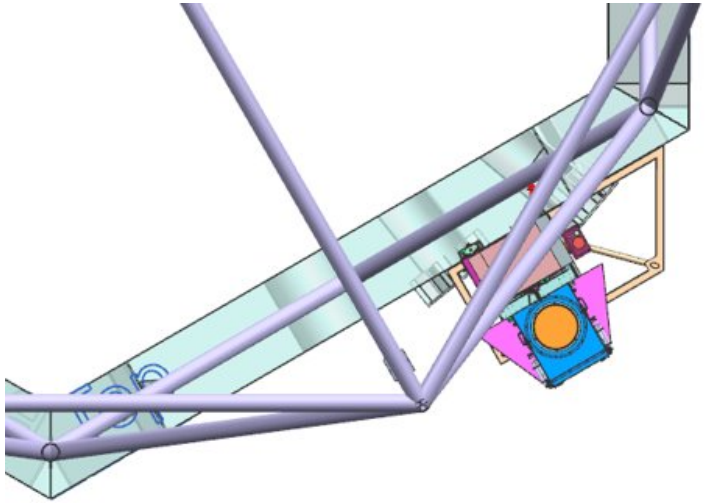


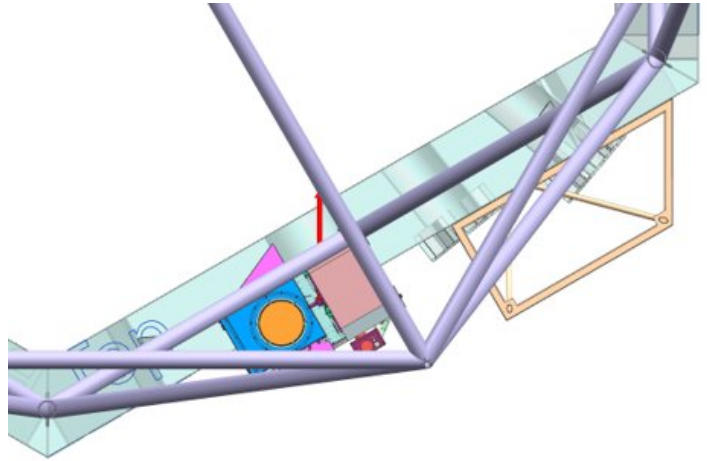
SIGHT/Robo-AO

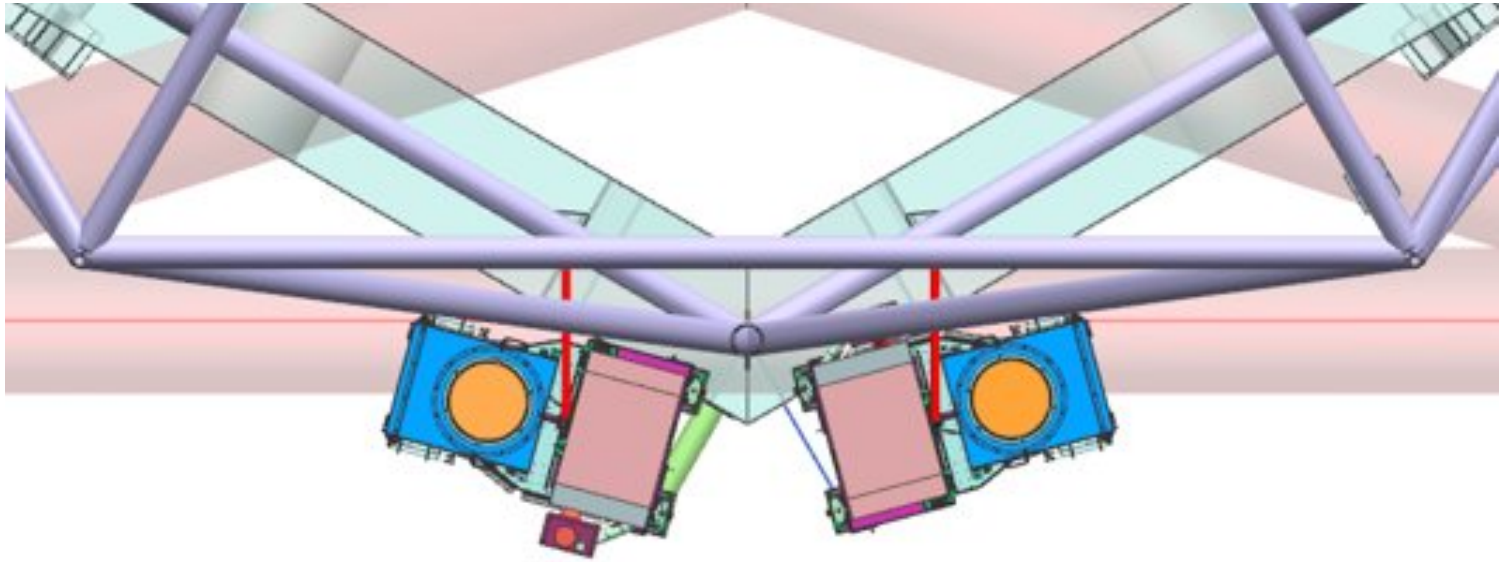


Modeling done by Tessa Vermeer (TNO) on potential mounting locations

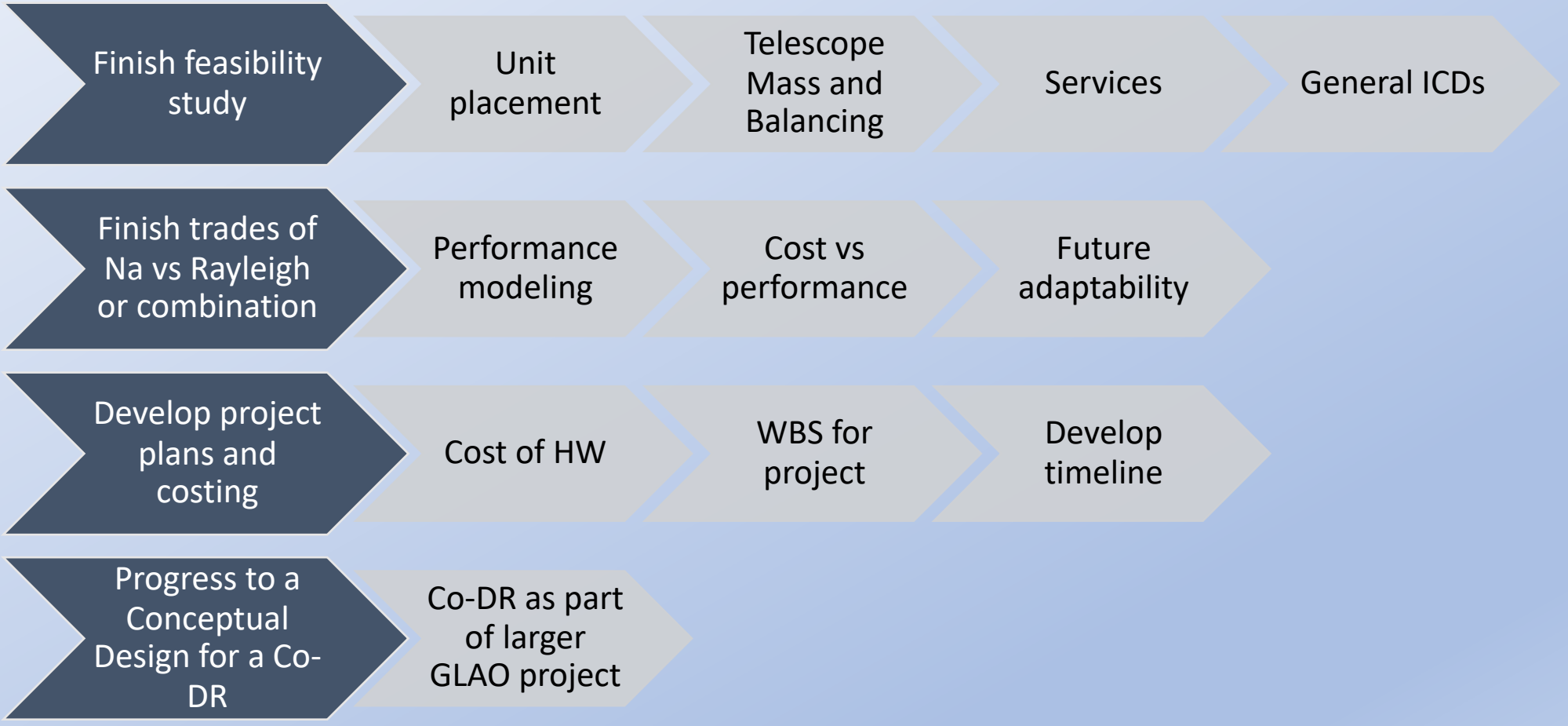
Feasibility of TNO package on elevation ring







Next Steps


Finish feasibility study
Unit placement
Telescope Mass and Balancing
Services
General ICDs
Finish trades of Na vs Rayleigh or combination
Performance modeling
Cost vs performance
Future adaptability
Develop project plans and costing
Cost of HW
WBS for project
Develop timeline
Progress to a Conceptual Design for a Co-DR
Co-DR as part of larger GLAO project


Mahalo