The **Semiconductor Guidestar Laser**: A novel, affordable, low SWaP sodium guidestar laser for adaptive optics tracking of space objects

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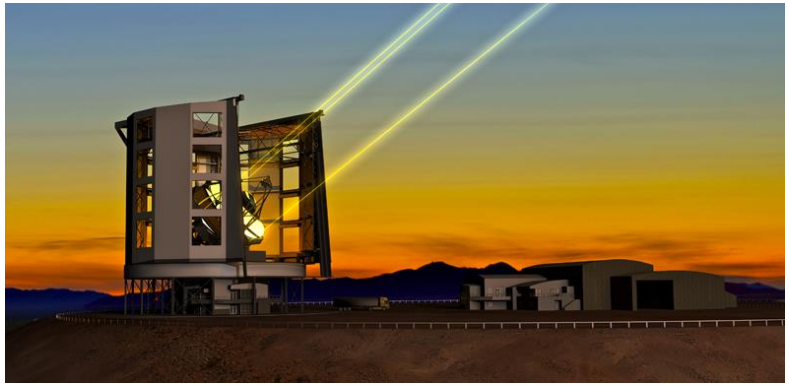
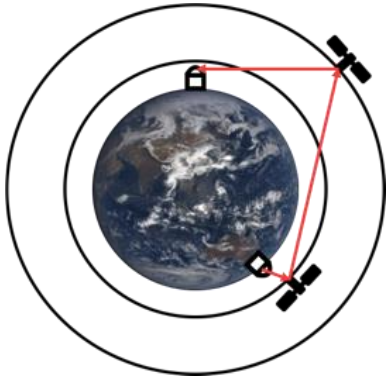
ANU Advanced Instrumentation and Technology Centre (AITC)
Mount Stromlo Observatory, Canberra, Australia

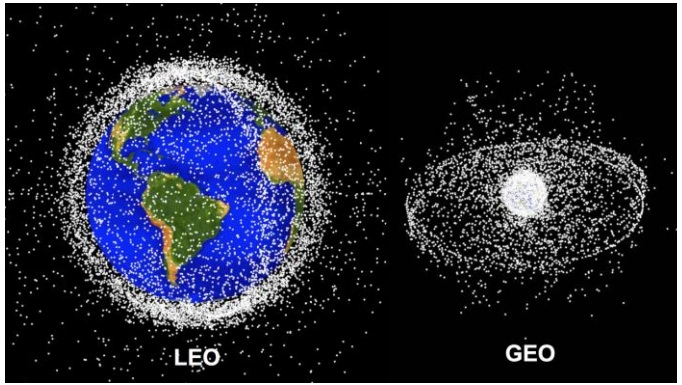
8 November 2018

Outline

- Adaptive Optics research @ ANU AITC
- Laser Guide Star Adaptive Optics (LGS AO) 101
- 4 generations of sodium guidestar laser technologies
- ANU **Semiconductor Guidestar Laser** program







Adaptive Optics Research @ ANU Advanced Instrumentation and Technology Centre (AITC)

- World-leading AO research and development team:
  - 8-9 AO/laser/RTC instrument scientists
  - 4-6 postgraduates & 10-20 undergraduates
  - Supported by 20-25 ANU AITC engineering staff
- ANU AO program: research funding & commercial contracts
  - Astronomy on 8-40m telescopes (e.g. ESO VLT, Gemini, Keck, Subaru, GMT, ELT): LGS AO, GLAO, LTAO, MCAO
  - Laser communications (e.g. DST Group, ACT Government, Quintessence Labs, NICT): horizontal, space to ground, and ground to space
  - Space Situational Awareness (e.g. SERC, KASI): AOI, AOTP

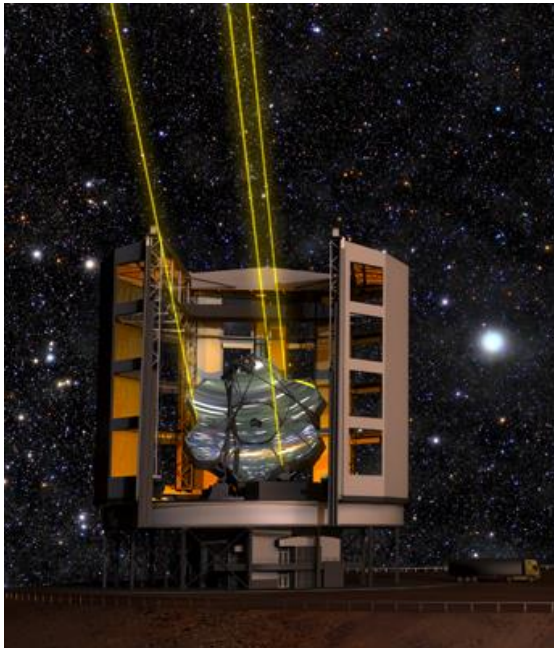


Image Credit: Giant Magellan Telescope Organization

Laser Guide Star Adaptive Optics (LGS AO) 101

- Adaptive Optics
  - **Wavefront sensor** measures wavefront distortions caused by atmospheric turbulence
  - **Deformable mirror** corrects for these distortions in real time
- Laser Guide Star
  - Provides a reference source if/where none is available

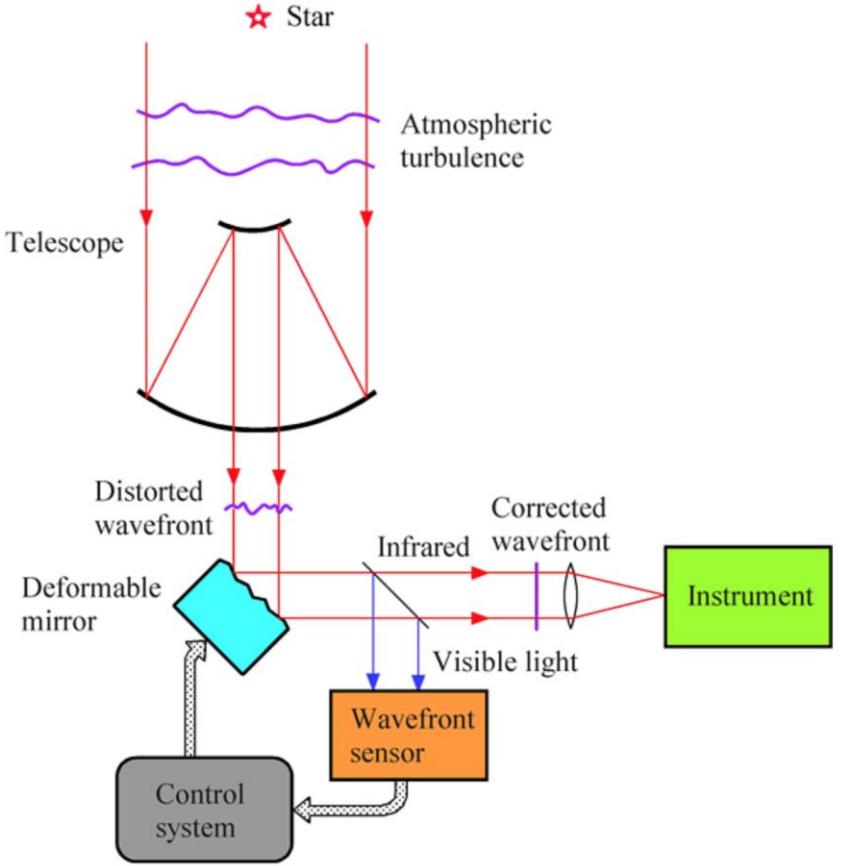
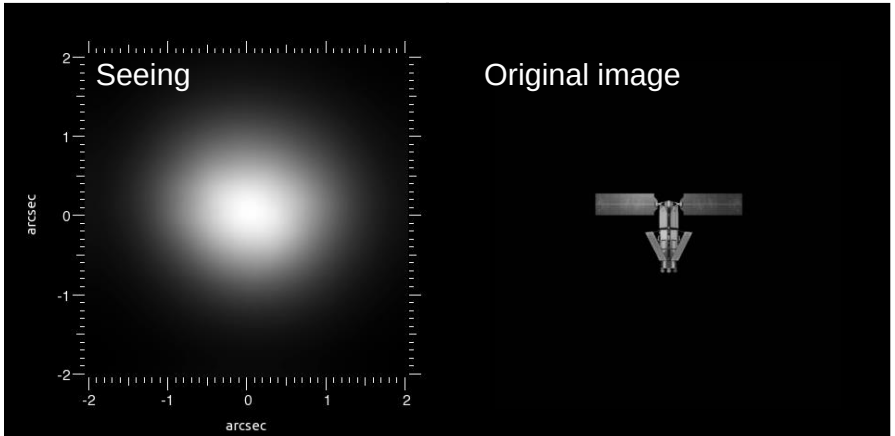


Image Credit: National Astronomical Observatory Japan

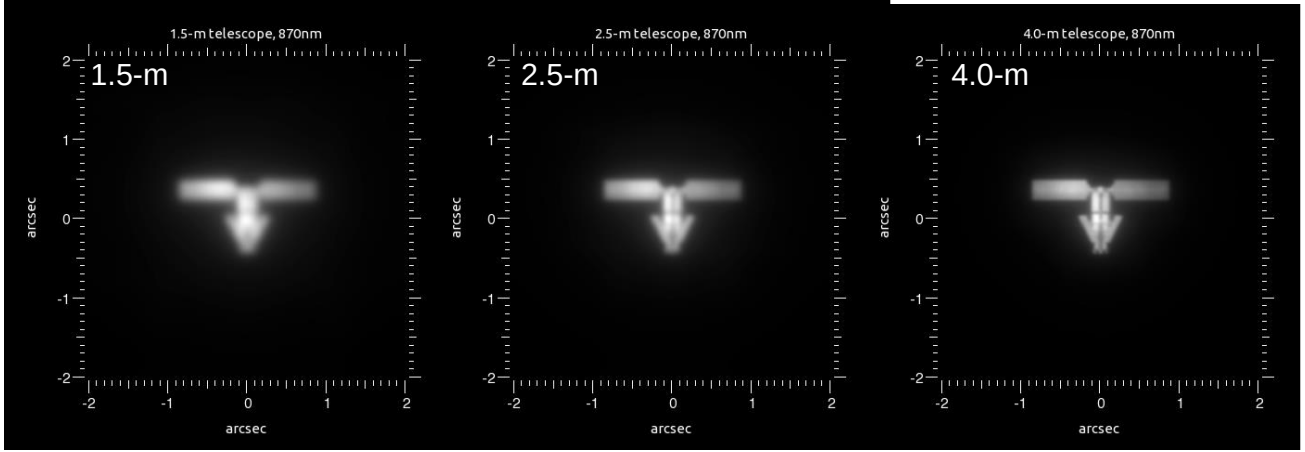
AO Imaging of space objects



Influence of telescope diameter

Example of an Iridium satellite (Strehl ratio ~ 30%)

AOI Simulations Credit: F. Rigaut (ANU)



AO Tracking & Pushing

- SERC Research Programs 1 & 4 (ANU, EOS Space Systems, Lockheed Martin)
- Objective: Mitigation of debris to debris collisions using photon pressure from AO-compensated high power IR laser

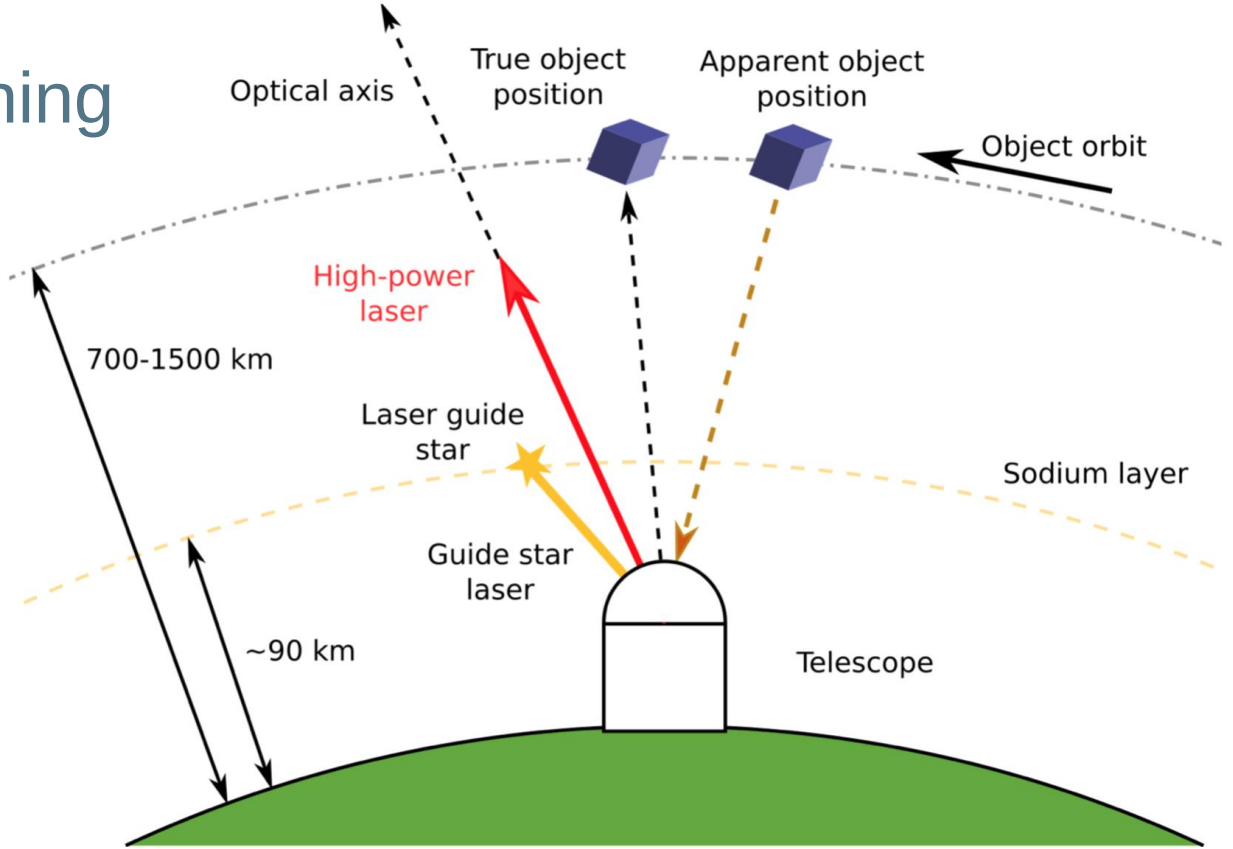
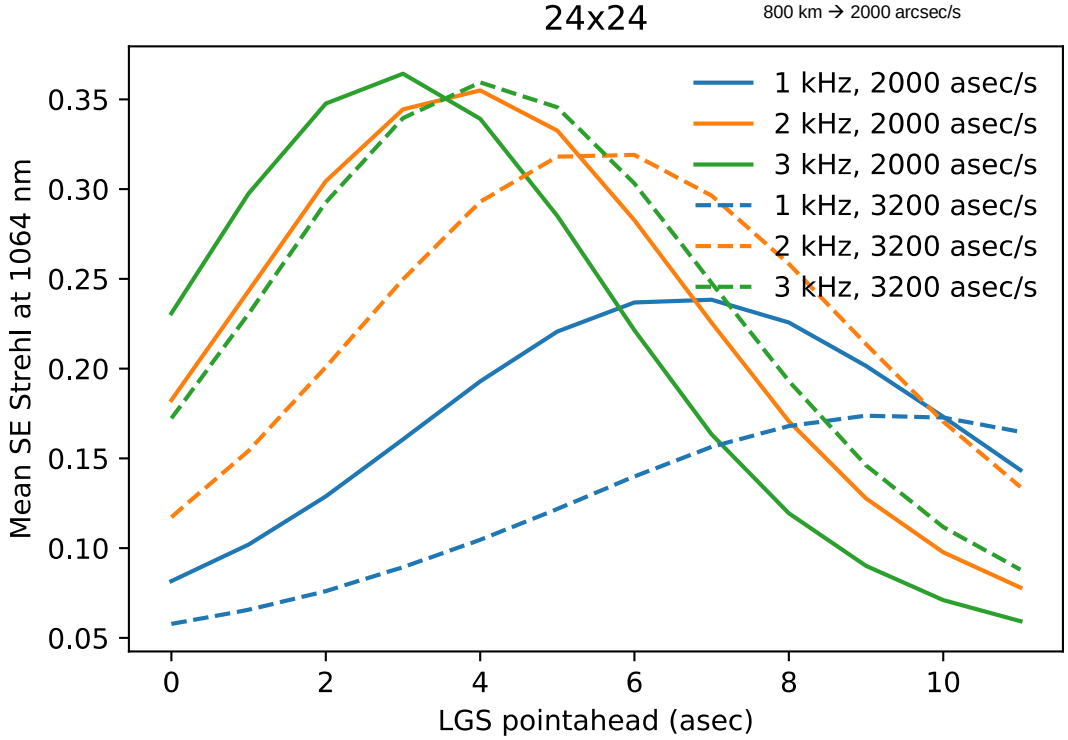


Image credit: D. Grosse (ANU)

Laser Guide Star Point Ahead Angle

- Study performed by Dr Visa Korkiakoski (ANU) for AO on 1064nm laser in 2” seeing
- Optimum LGS point ahead boosts AO performance in all configurations (LEO and GEO) by a factor ~2 to 3
  - 2-10 arcsec typical
- Optimum angle varies with object velocity & AO loop rate
  - Lower altitude → Greater velocity → Larger angle
  - Higher loop rate → Smaller angle

LEO objects:
500 km → 3200 arcsec/s
800 km → 2000 arcsec/s



AO Simulation credit: V. Korkiakoski (ANU)

Friday 9 November | INTERNATIONAL WORKSHOP ON SPACE DEBRIS MANAGEMENT

The John Curtin School of Medical Research
131 Garran Rd, Acton
Workshop location

	START TIME	END TIME	PAPER TITLE	PRESENTING AUTHOR	AFFILIATION
Session 1: Sensors & Satellite Tracking Co-Chairs: Michael Pearlman Erricos Pavlis Giuseppe Blanco **Finkel Theatre**	08:30	09:00	Opening Session and Keynote Address	Moriba Jah	University of Texas at Austin and SERC International Research Management Committee
	09:00	09:15	SERC Research Program 1 Review: Remote manoeuvre of space debris using photon pressure for active collision avoidance	Craig Smith	EOS Space Systems, Australia
	09:15	09:30	Adaptive optics corrected imaging for satellite and debris characterisation	Michael Copeland	Australian National University / Space Environment Research Centre, Canberra, Australia
	10:15	10:30	Multi-kW high beam quality CW laser for space debris manoeuvring	Yue Gao	EOS Space Systems, Australia
Session 4: Mitigation & Remediation Session	15:30	15:45	Space Environment Research Centre: Space segment overview	Benjamin Sheard	Space Environment Research Centre, Mt Stromlo, Australia; EOS Space Systems, Australia
	16:45	17:00	Collision avoidance using ground based lasers	Liam Smith	Lockheed Martin, Colorado, United States

Sodium Guidestar Laser Technology State of the Art

- Review paper: d'Orgeville & Fetzer, Proc. SPIE 9909, 99090R, 2016
- Three generations of sodium guidestar lasers to date:

ALFA CW dye laser @ Calar Alto Observatory (Spain)

1st Gen. (1990s)

50W CW mode-locked solid-state laser @ Gemini South (Chile)

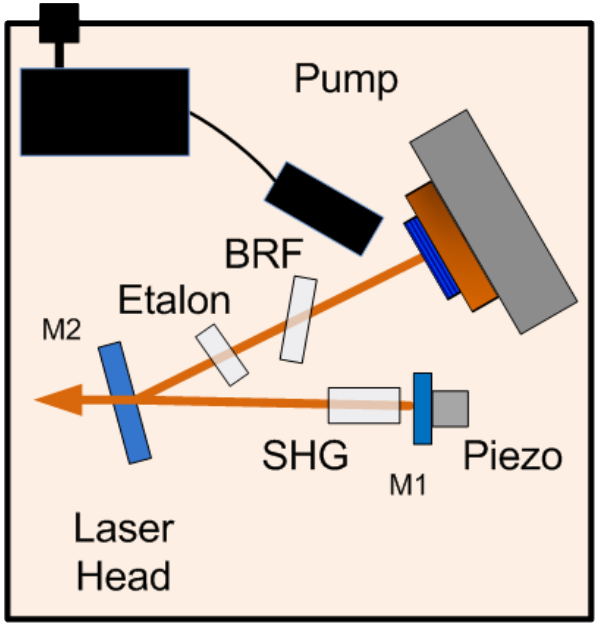
2nd Gen. (2000s)

20W Toptica SodiumStar fibre laser @ Keck Observatory (Hawaii, USA)

3rd Gen. (2010s)

Semiconductor Guidestar Laser Program

- 4th gen. sodium guidestar lasers (~2020s)
  - Based on semiconductor laser technology
  - a.k.a Vertical External-Cavity Surface-Emitting Lasers (VECSEL)
  - a.k.a Optically Pumped Semiconductor Lasers (OPSL)
- Technology demonstrated and commercialised at other λ
- Low component count leads to:
  - Small SWaP (Size Weight and Power)
  - Affordable procurement cost
  - Reduced maintenance cost



Intra-cavity doubled OPSL

(Image credit: Areté Associates)

Semiconductor Guidestar Laser Program

- ANU-led project to build a **prototype** for use in astronomy, space, and laser communications
- Project funding to date:
  - Government: Australian Research Council
  - Academia: ANU, UNSW
  - Observatories: AAO, GMT
  - Industry: EOS Space Systems, Lockheed Martin
- Laser vendor:

Areté Associates

Australian Government
Australian Research Council

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Laser guide star within reach

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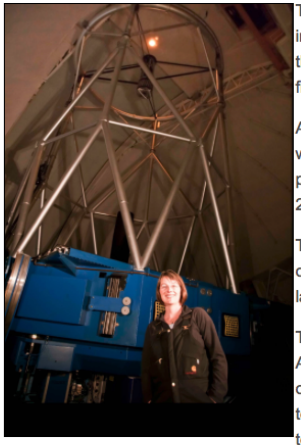


The creation of a new laser system for the first Australian laser guide star that will have important and far-ranging uses in astronomy, satellite tracking and mitigation of the threat of space debris will soon be possible, following the award of a $502,453 grant from the Australian Research Council (ARC).

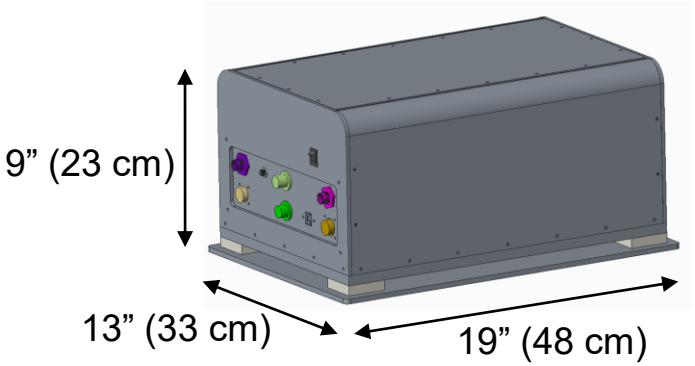
Associate Professor Celine d'Orgeville, from The Australian National University (ANU), will lead the successful ARC Linkage Infrastructure, Equipment and Facilities (LIEF) project announced as part of the ARC Major Grants Announcement on 1 November 2016. The ARC is providing $28.6 million for 48 new LIEF projects.

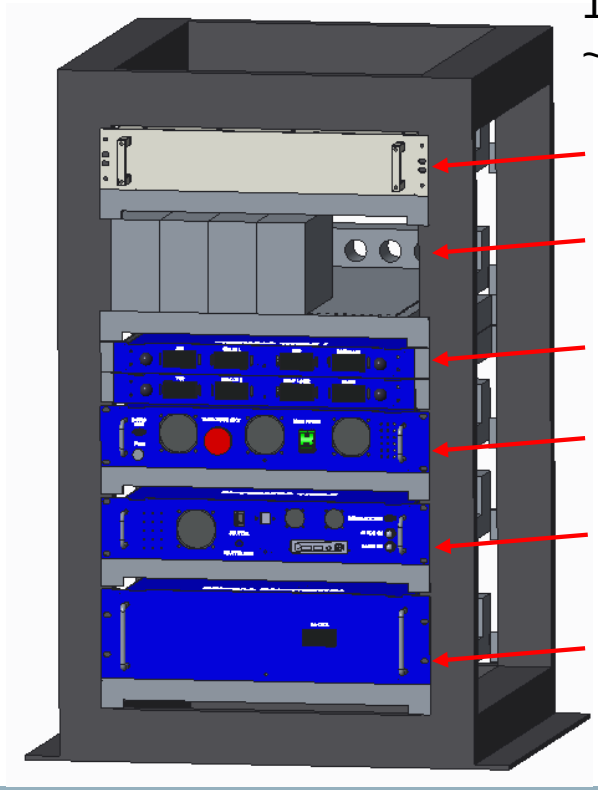
The new project, to commence in 2017, will use semiconductor laser technology as a cost-effective, highly reliable and compact alternative to expensive, inefficient, bulky laser systems that are currently used.

The new infrastructure will enable the production of the first sodium laser guide star in Australian skies, and will secure Australia's position as the premier provider of commercial-grade laser guide star adaptive optics systems for civil and defence telescopes around the world. This laser has wide scientific appeal for research with telescopes in astronomy, and for satellite tracking and mitigation of the threat of space debris.

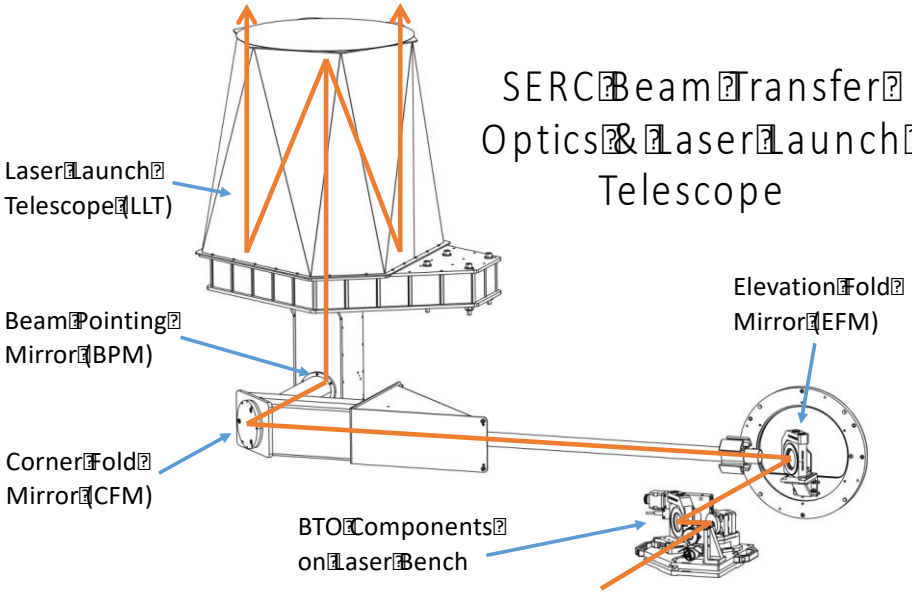
Laser Prototype Fabrication Status

- Design of Laser Head and Laser Rack is nearly complete
- Detailed design pending final lab results and details of interfaces to EOS telescope
- Delivery to ANU Mount Stromlo Observatory planned in 2019 Q2

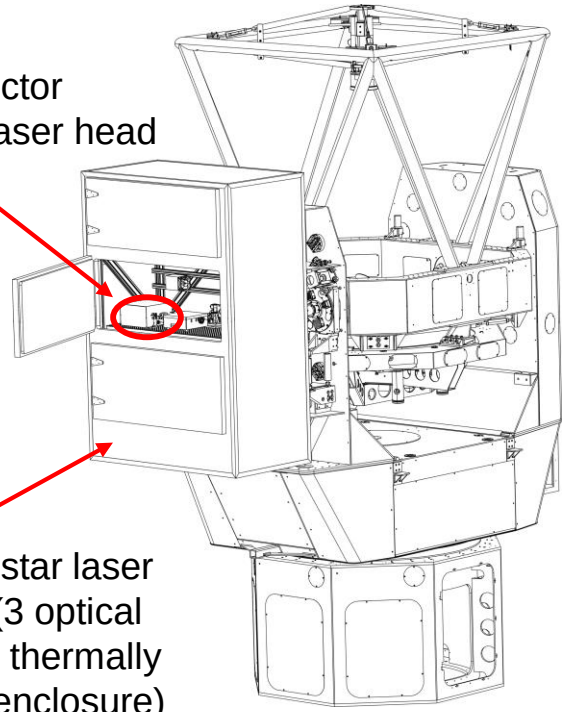




Laser Installation & Testing @ Mount Stromlo (2019)



ANU/Areté semiconductor guidestar laser head

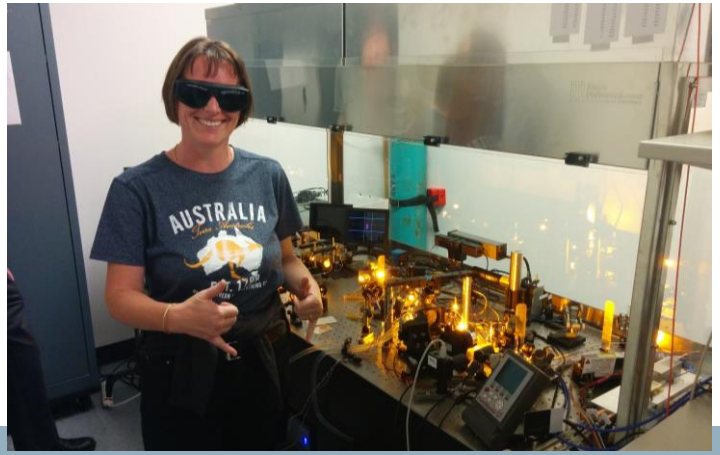


EOS guidestar laser enclosure (3 optical benches in thermally controlled enclosure)

SPACE DEBRIS POSTER SESSION

Friday 9 November (during lunch)

SESSION	POSTER NUMBER	PAPER TITLE	PRESENTING AUTHOR	AFFILIATION
Session 1: Sensors & Satellite Tracking	SD5	Development and architecture of the EOS Guide Star Laser	James Webb	EOS Space Systems, Queanbeyan, Australia
	SD2	The Semiconductor Guidestar Laser: A novel, affordable, low SWaP sodium guide star laser for adaptive optics tracking of space objects	Celine d'Orgeville	Australian National University / Space Environment Research Centre, Canberra, Australia



Thank you!
Any questions?