

Nordic Optical Telescope

Back to the Future

BACK
TO THE FUTURE II



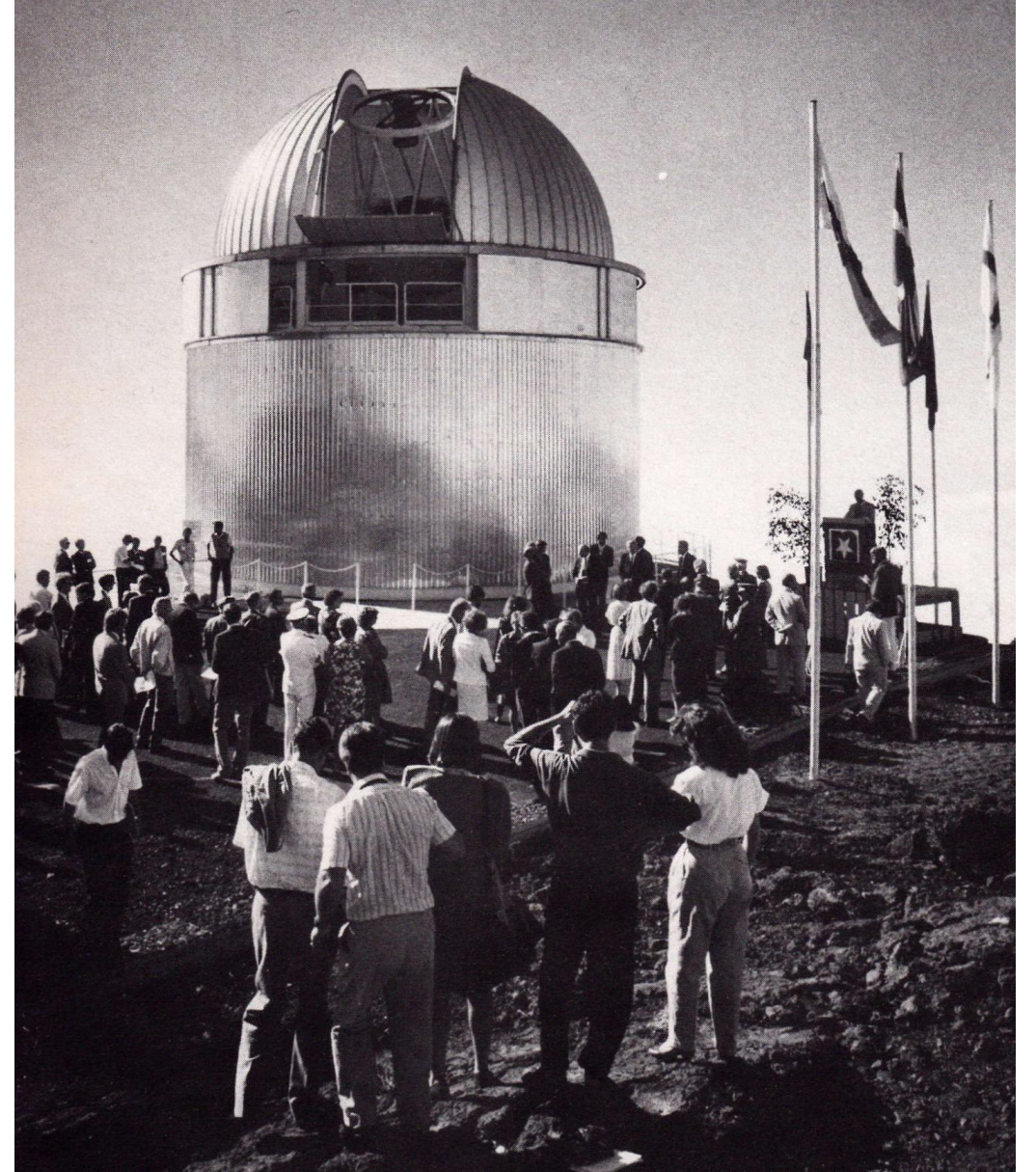
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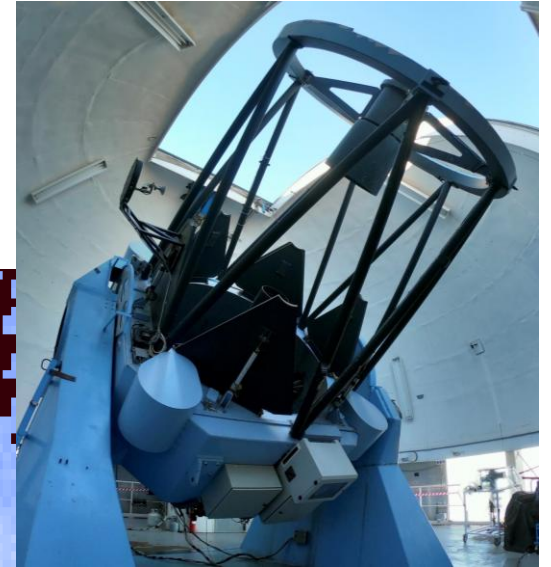
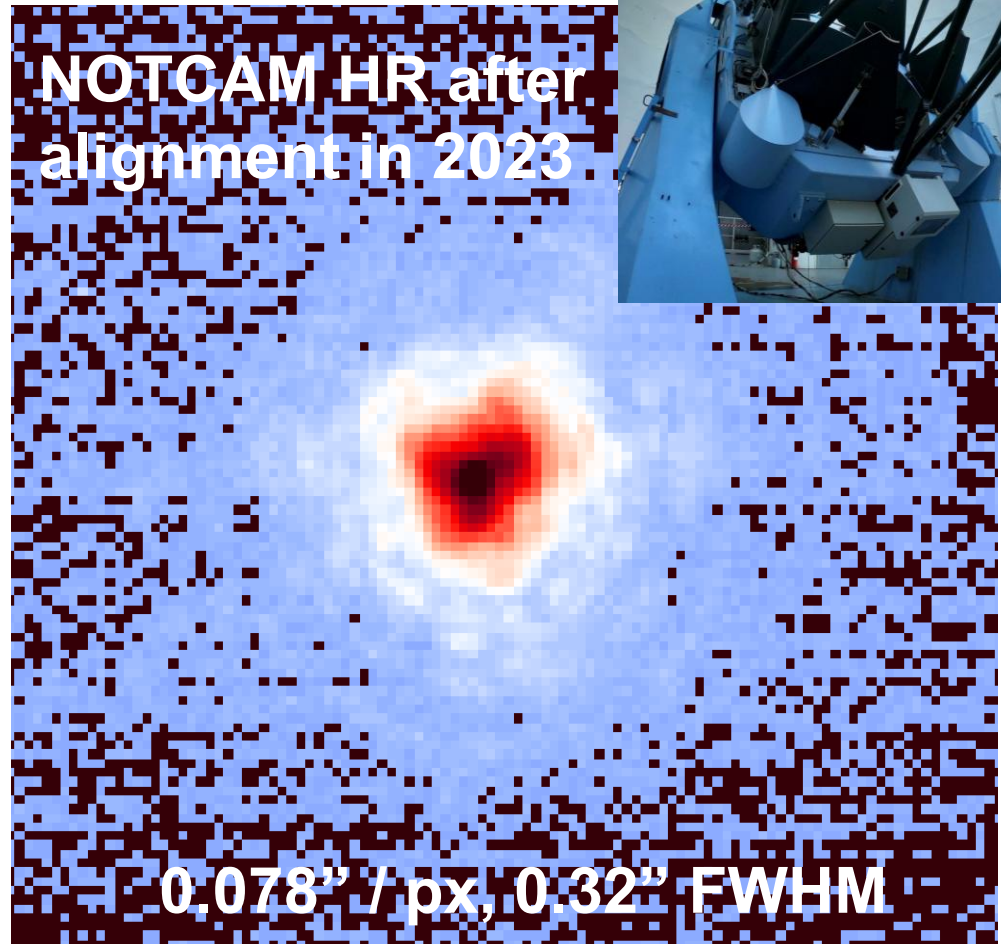
Nordic Optical Telescope

- Inaugurated in 1989
- Advanced for its time
 - Fastest and thinnest M1
 - Active optics
 - Aerodynamic dome design
 - Low dome-seeing contribution
- 1995 to 2010 saw development of versatile instrumentation suite
- Flexible operations model still continuously developed



Optical performance

- 0.4" FWHM PSF → Angular resolution and sensitivity are natural seeing and/or instrument sampling limited
 - Theoretical limit after correction of low-order aberrations 0.2"
- Great potential for mid-sized telescope with AO !



Technical status

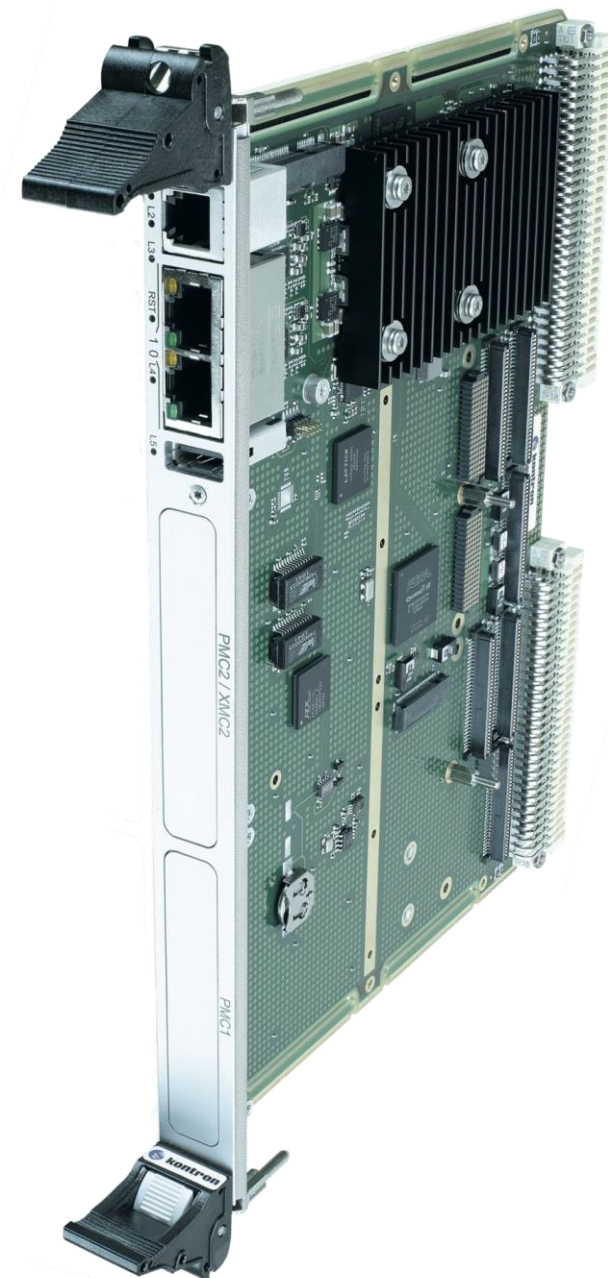
- Extremely low downtime $\sim 1\%$ \rightarrow enabled by large spare stock, however...
- ...the spare stock is starting to run low, and some systems already without original spares \rightarrow Time to do something!
- Modification to the control system are complex and require careful planning
- Workaround \rightarrow Develop I/O compatible replacements \rightarrow Time consuming

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- ***Conclusion: larger changes required soon → Opens up potential for performance increases and even new science cases***

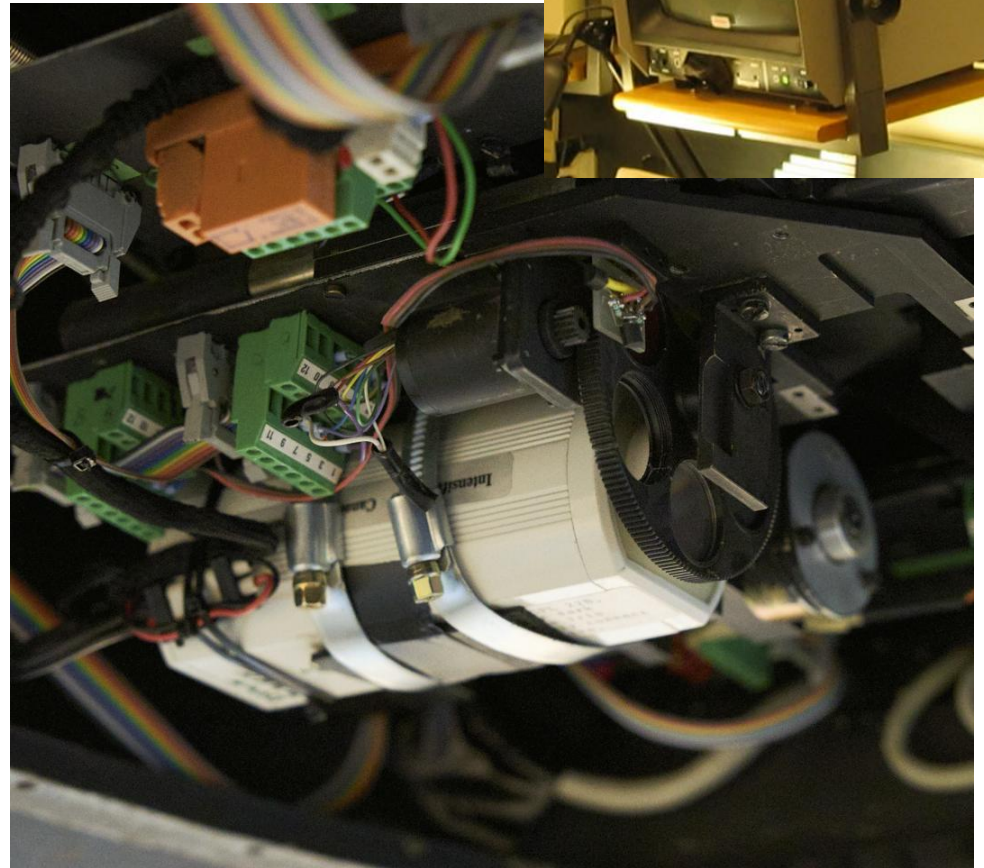
Upgrade needs – TCS CPU

- Upgrade path: replace current single board computer (SBC) with a modern alternative
 - Clock speed from 60MHz to 1GHz
 - Memory from 64MB to 4GB
 - Operating system from OS-9 to Linux
- Project status:
 - SBC running on TCS development rack
 - TCS code compiled and runs on new CPU
 - Serial terminal UI interface work in progress
 - Full communication over VMEbus pending
- Future:
 - Extended VMEbus testing and UI operation with virtual data
 - Start moving I/O from VMEbus to EtherCAT



Upgrade needs – Auto-guider

- Autoguider detector replacement has been discussed for long time
- Spare TV camera exists with higher noise than the operational one → *Not desirable*
- Solution:
 - Replace with a modern CMOS detector
- Challenges:
 - Modern CMOS pixels tiny compared to the ICCD → $\sim 5\mu\text{m}$ vs. $25\mu\text{m}$ → Focal reducer needed
 - New software interface to TCS needed → Development under old system is a challenge!



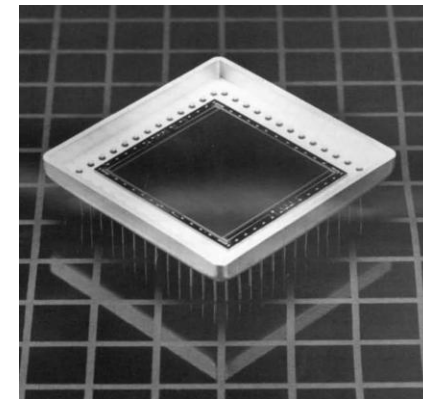
Upgrade needs - power amplifiers

- Impossible to get an original spare or one-to-one swap-in products
- Rotator power amplifiers – no spares
 - Comparable amplifiers purchased
 - I/O interface designed to imitate the old amps
 - Live test made with the new spares → Further servo tuning required
- Guide probe power amplifiers – no spares
 - Comparable amplifiers purchased
 - I/O interface developed but not tested on the telescope
- Altitude and azimuth drive Proportional-Integral (PI) boards
 - Custom design, complex analog filter profile
 - Spares prepared a couple years ago
 - Simulated in software, tested on bench top, but not live tested

TCS changes will allow...

- ...easier to maintenance for the younger generation tech staff
- ...transition from VMEbus to EtherCAT
- ...expansion of software features
- ...integration of new hardware

STANCAM replacement



- STANCAM is a Tektronix TK1024, 1024 x 1024 x 25 μ m
→ Higher QE, lower RON and dark, and shorter readout time achievable with a modern alternative → Retires Cryotiger cooler, less maintenance
- New sensor brings improved fiber guiding for FIES, higher quality stand-by visual photometry, and possibility to do fast photometry and speckle imaging (*new!*)
- *Requirements:* 3' x 3' FoV in folded Cassegrain, UBVRI filters + close focus for fiber-guiding

Adaptive optics

- TNO seeking consortium members to “mass produce” adaptive M2 units → NOT has been contacted
- Design based on hybrid variable reluctance actuators
- NOT M2 is in a suitable size range for the mass production
- First results from 3.2-meter NASA IRTF on Hawaii (Lee et al., 2024)

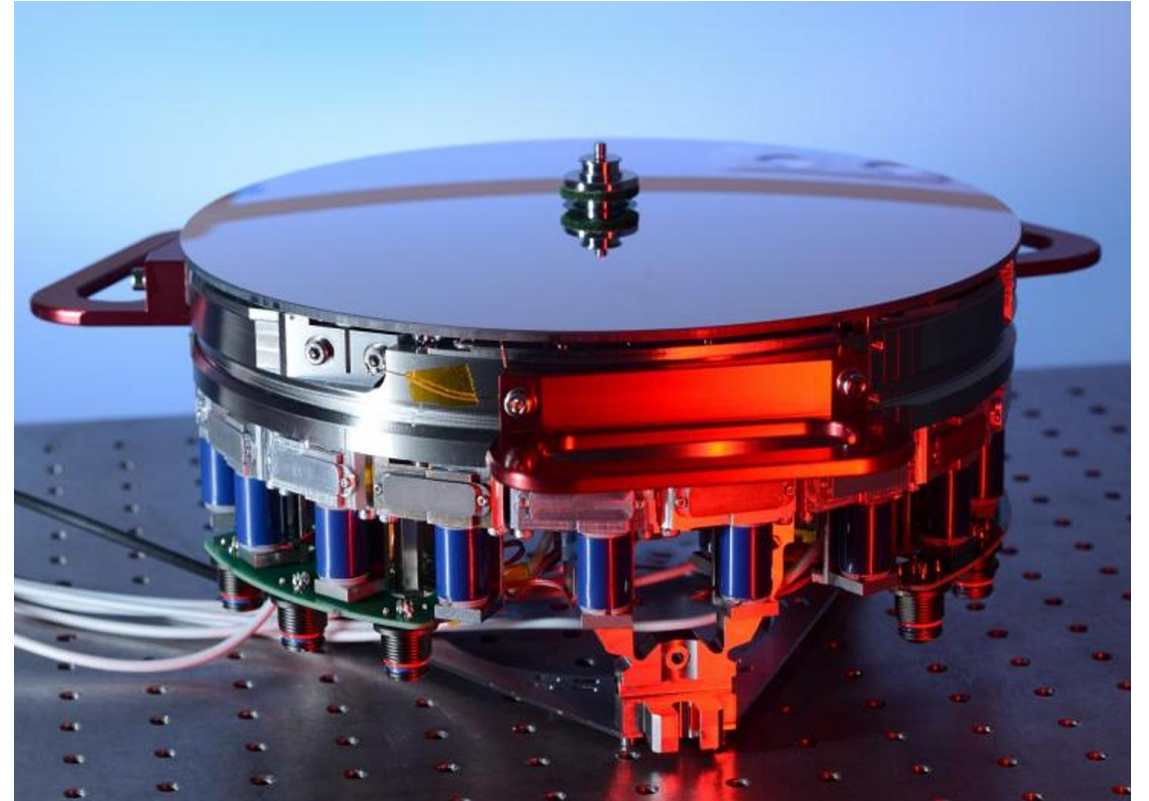


Figure: NASA IRTF adaptive M2 unit
See Lee et al. (2024), DOI: [10.1117/12.3016132](https://doi.org/10.1117/12.3016132)

Future role of NOT

- Fills a unique locus in time-domain astronomy with...
 - ...versatile instrumentation
 - ...sufficiently large primary for low- to mid-res spectroscopic follow up
 - ...fast slewing speed and Rapid Response Mode (RRM)
 - ...differential tracking capabilities further expandable depending on interest
- Testbed and steppingstone for technology demonstration
 - Testbed for Skipper CCDs, SPADs, black silicon, astrophotonics
- Sensitivity gains available
 - Enhanced NIR performance with silver coatings (similar to ELT)
 - Beam steering or adaptive optics (much more achievable than before)

Summary

- To maintain the impressively low downtime investment needed soon to the telescope hardware → ***Opens up new opportunities***
- NOT's versatility in terms of instrumentation and observing modes is an advantage → ***Should be maintained in the future***
- NOT offers a platform to showcase technological breakthroughs which allow potential performance improvement of the telescope and its instrument suite → ***Should be utilized***

Thank you for your attention!

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**Draft report on technical status
and potential upgrades available, feedback is welcome**

[https://www.not.iac.es/news/reports/NOT_tech_status_and_upgrade_plan PRELIMINARY.pdf](https://www.not.iac.es/news/reports/NOT_tech_status_and_upgrade_plan_PRELIMINARY.pdf)

Image: Stephan's Quintet recorded with the NOT, processing Benjamin Hauptmann
<https://www.not.iac.es/general/photos/astronomical/extragalactic/>