# Detector Controllers

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# Instruments of the ESO VLT / VLTI need detectors

# Astronomical Instruments of the ESO VLT / VLTI need detectors

FORS2

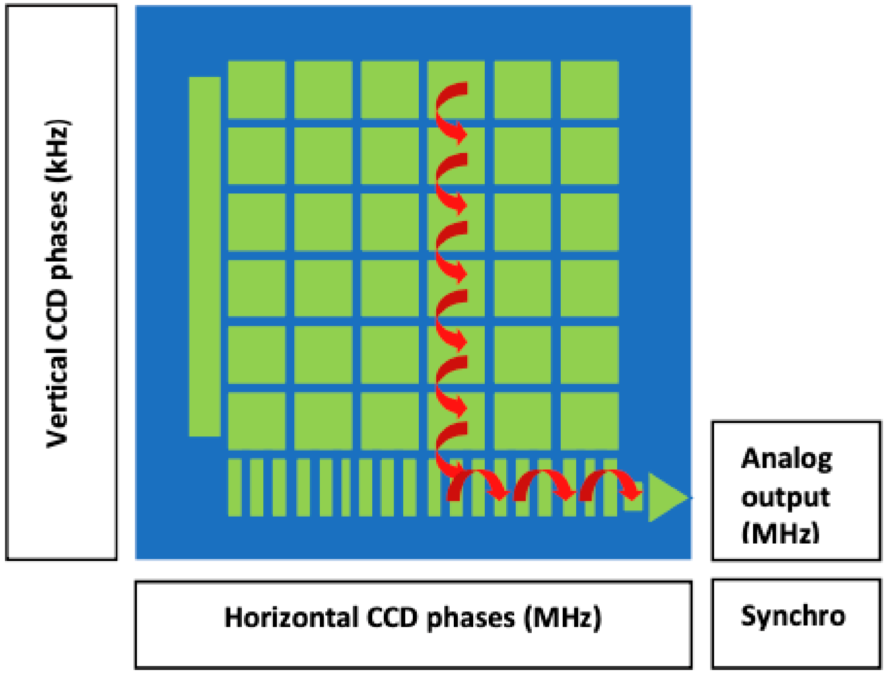
MUSE

UVES

GRAVITY

# Principle of Operation
# CCD, CMOS & IR Detectors

# CCD Operating Principle

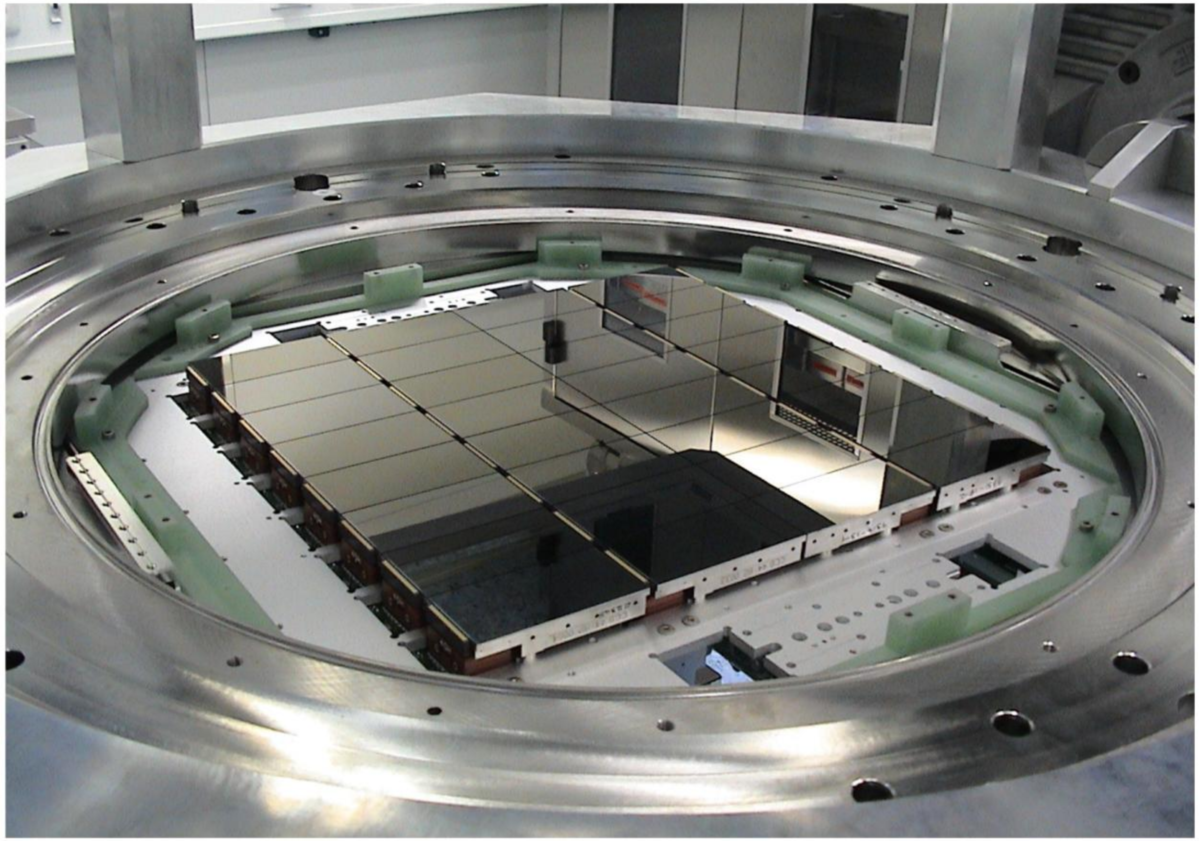



CCD = Photon-to-electron conversion (analog)

**CCD (Charge-Coupled Device)**

- Silicon-based
- Light generates charge in each pixel (photoelectric effect).
- Charges are transferred pixel-to-pixel to a readout amplifier.
- Spectral range: ~350 nm to ~1050 nm
- Peak QE: Often 80–95% in the 500–700 nm range for back-illuminated devices.
- Pros: Low noise, high image quality
- Use: Astronomy, scientific imaging

# OmegaCAM detector mosaic – VST Telescope



32 CCDs - 16 x 16 k - 1x1° FOV + 4 tracker - **288** million pixels !

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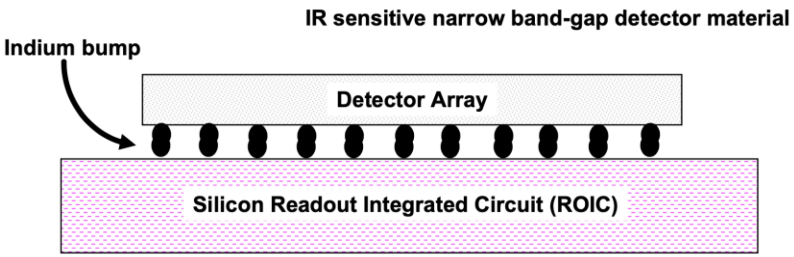
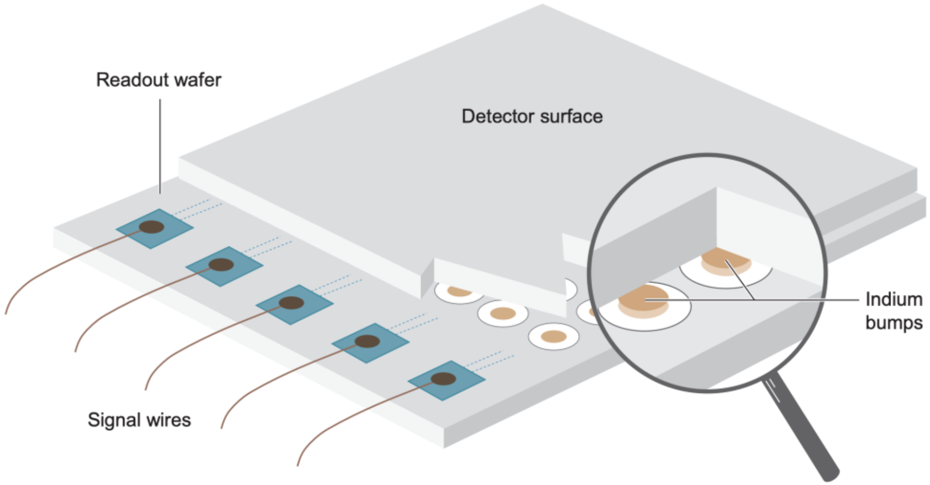
# IR Detector – Operating Principle

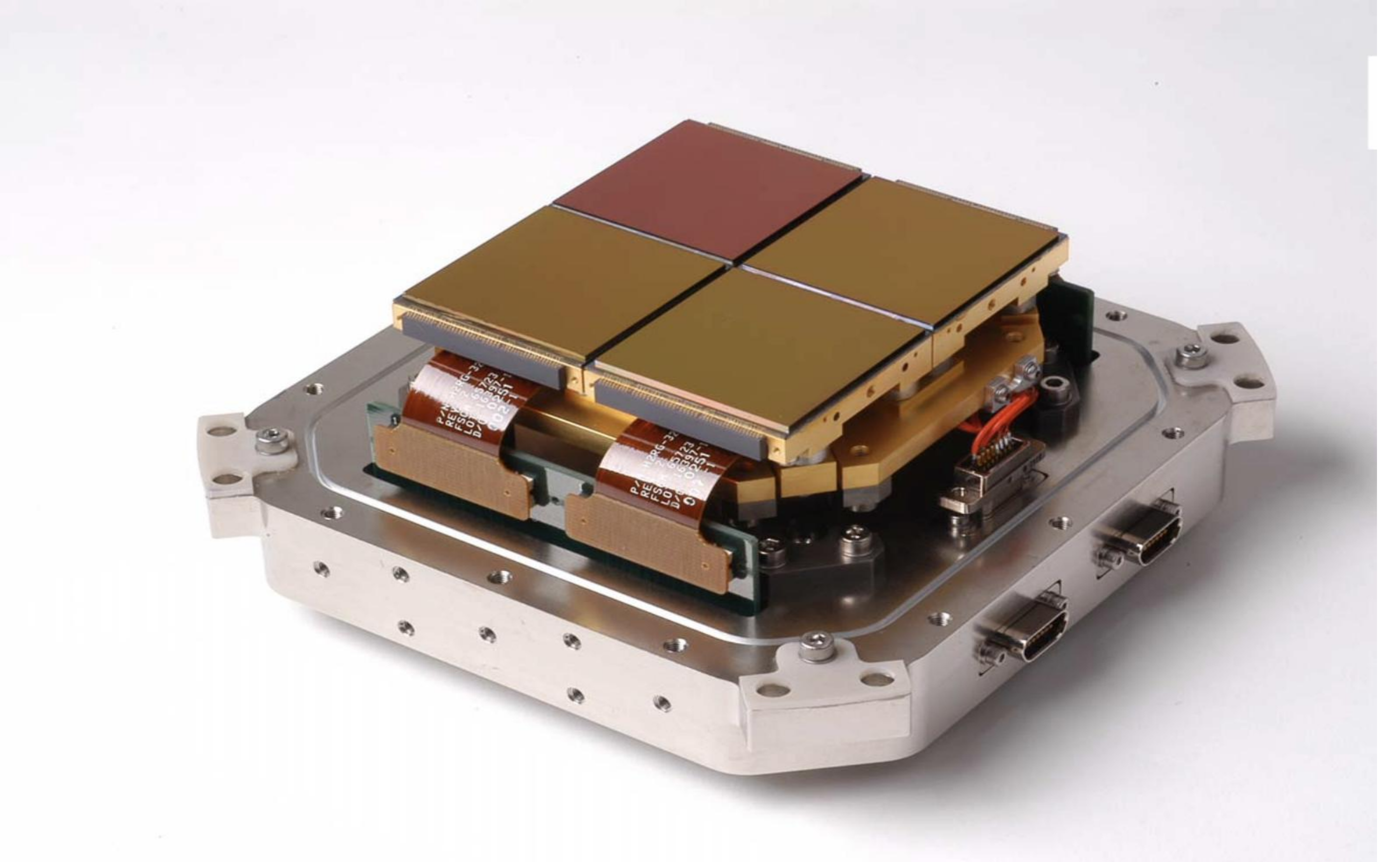



**IR Detectors (e.g., HgCdTe, InSb)**

- Absorb IR photons → generate electron-hole pairs.
- HgCdTe (Mercury-Cadmium-Telluride)
- Common astronomy formats:
  - Short-Wave IR (SWIR): 0.8–2.5 µm
  - Mid-Wave IR (MWIR): 2.0–5.3 µm
  - Long-Wave IR (LWIR): 8–14 µm (less common in astronomy).
  - HAWAII-2RG or H4RG arrays typically used in 0.8–2.5 µm.
- Often hybridized with a Readout Integrated Circuit (ROIC).
- Require cooling to reduce thermal noise. (~75 K – Cold head )
- Use: Infrared astronomy, thermal imaging

# Hawk-I Instrument Mosaic Package



2x2 Detectors - 2Kx2K Hawaii-2RG mosaic for Hawk-I

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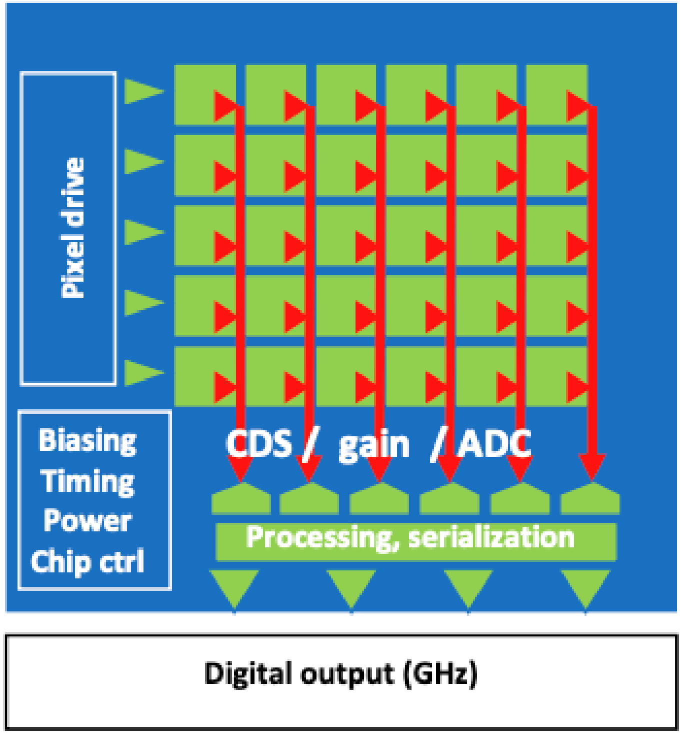
# CMOS Operating Principe

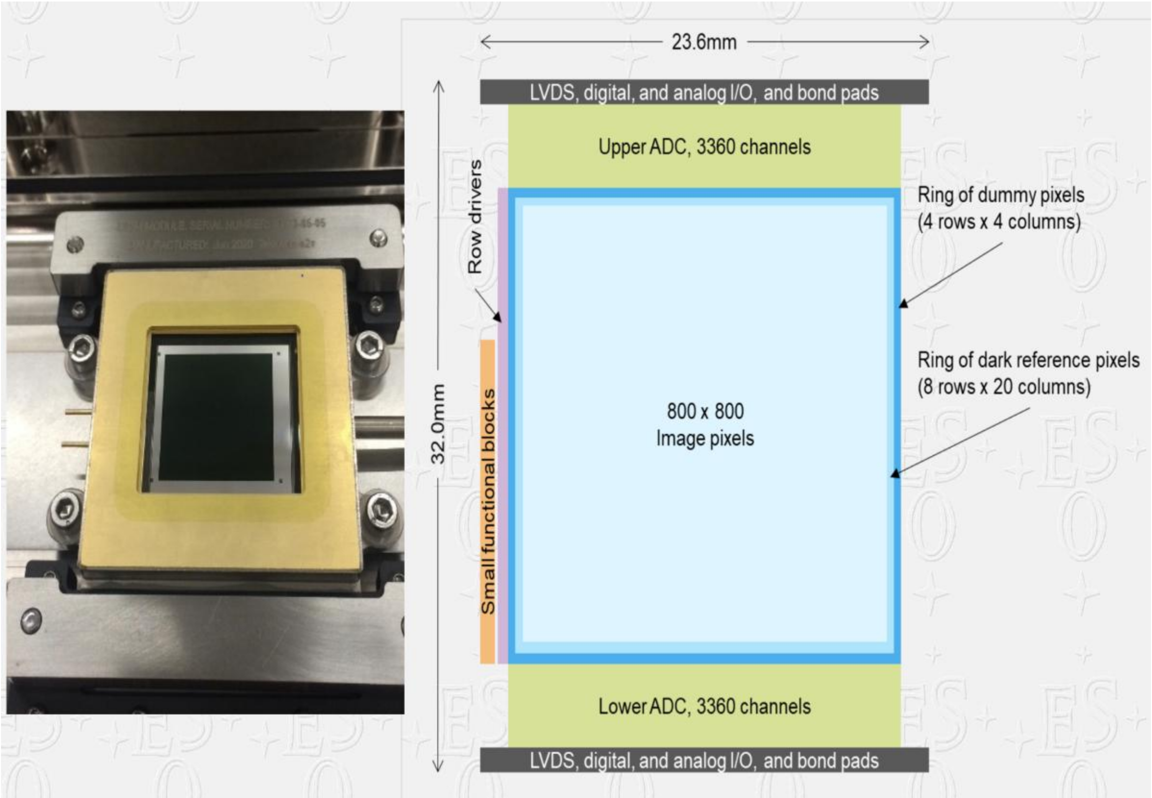



CIS = Photon-to-Voltage conversion (digital)

**CMOS (Complementary Metal-Oxide Semiconductor)**

- Each pixel has its own amplifier and readout circuit.
- Spectral range: ~350 nm to ~1050 nm
  - Similar to CCDs, since both use silicon photodiodes.
- Specialized coatings/microlenses can improve UV or NIR sensitivity.
- Peak QE: 60–85% (scientific CMOS can reach >90% with back-illumination).
- Parallel readout allows faster speeds.
- Pros: Low power, fast, integrated electronics
- Use: Consumer, space, adaptive optics and now Astronomy (VISIBLE)

# Example of CMOS detectors




**LISA (Large vISble cAmera – LVSM (WFS camera for ELT)**

- The Large Adaptive Optics Visible Sensor Module ("LVSM").
- For use in high-order laser guide star (LGS) AO systems at visible wavelengths, as well as telescope guiding.

# Evolution of ESO Detector Controllers

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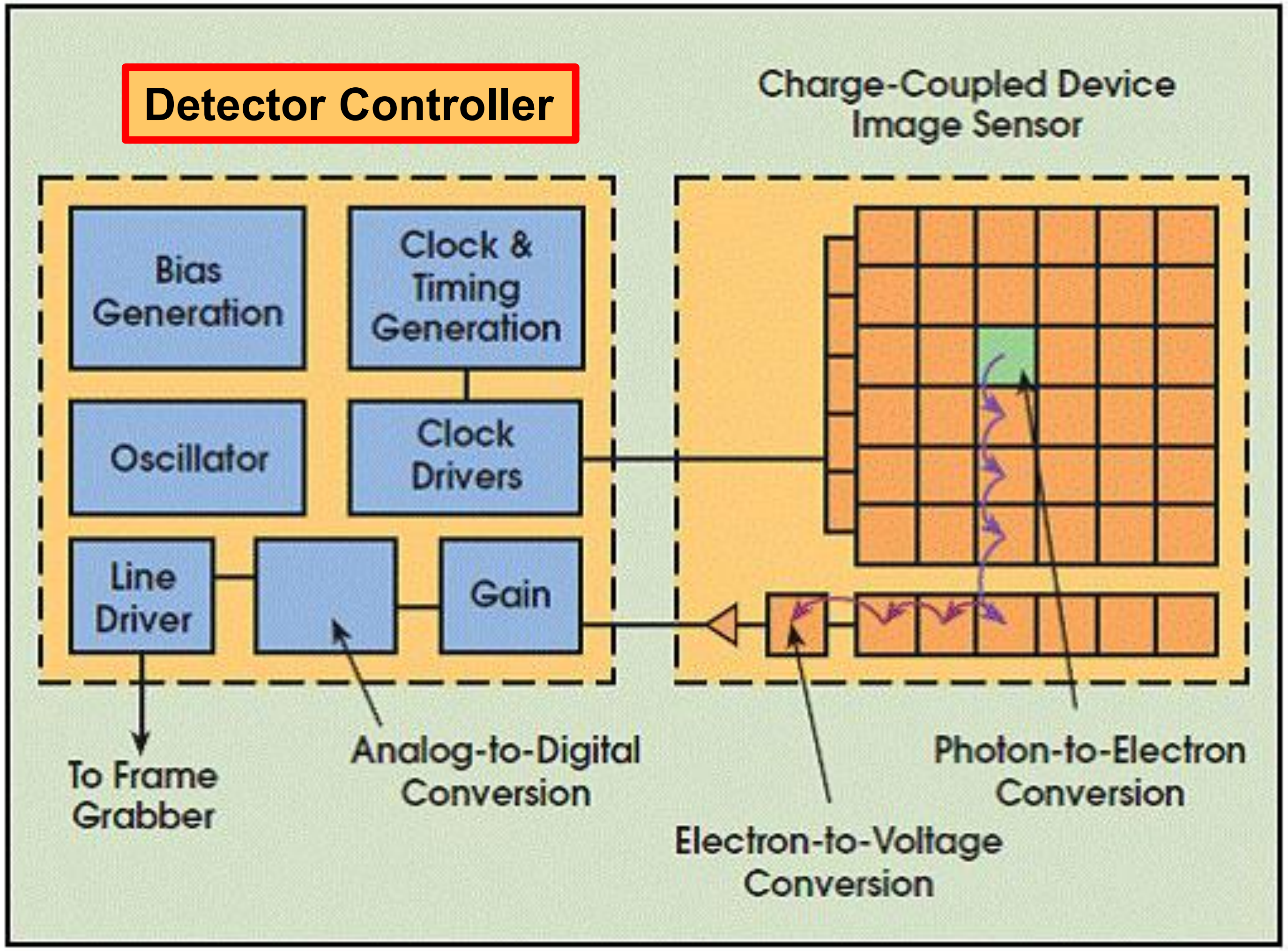


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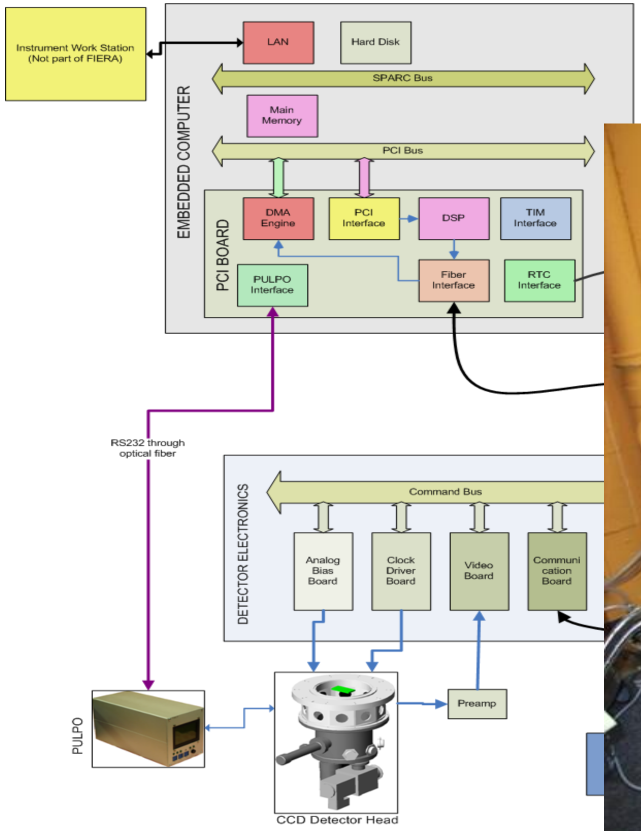
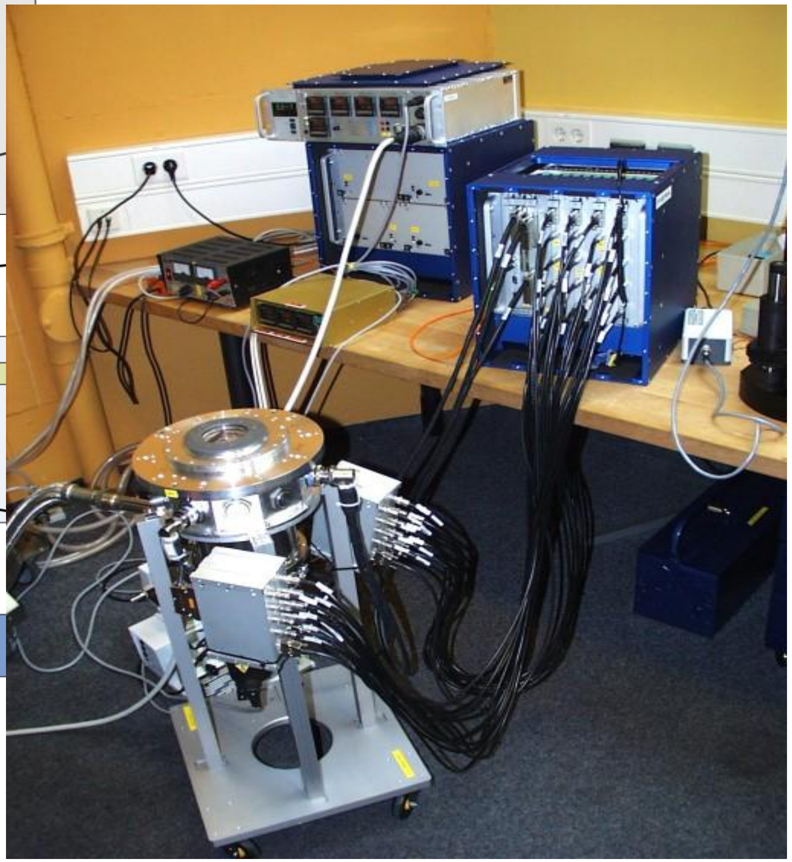
# Evolution of ESO Detector Controllers

**FIERA (F**ast **I**mager **E**lectronic **R**eadout **A**ssembly**)**

**(Visible Spectrum)**

- The first FIERA prototype was successfully demonstrated in October 1996 – DSP-Based
- ESO developed a new generation CCD controller for the Very Large Telescope (VLT) and La Silla Observatory
- Operated reliably for decades and still in use across multiple instruments (FORS2, UVES, X-SHOOTER, FLAMES)

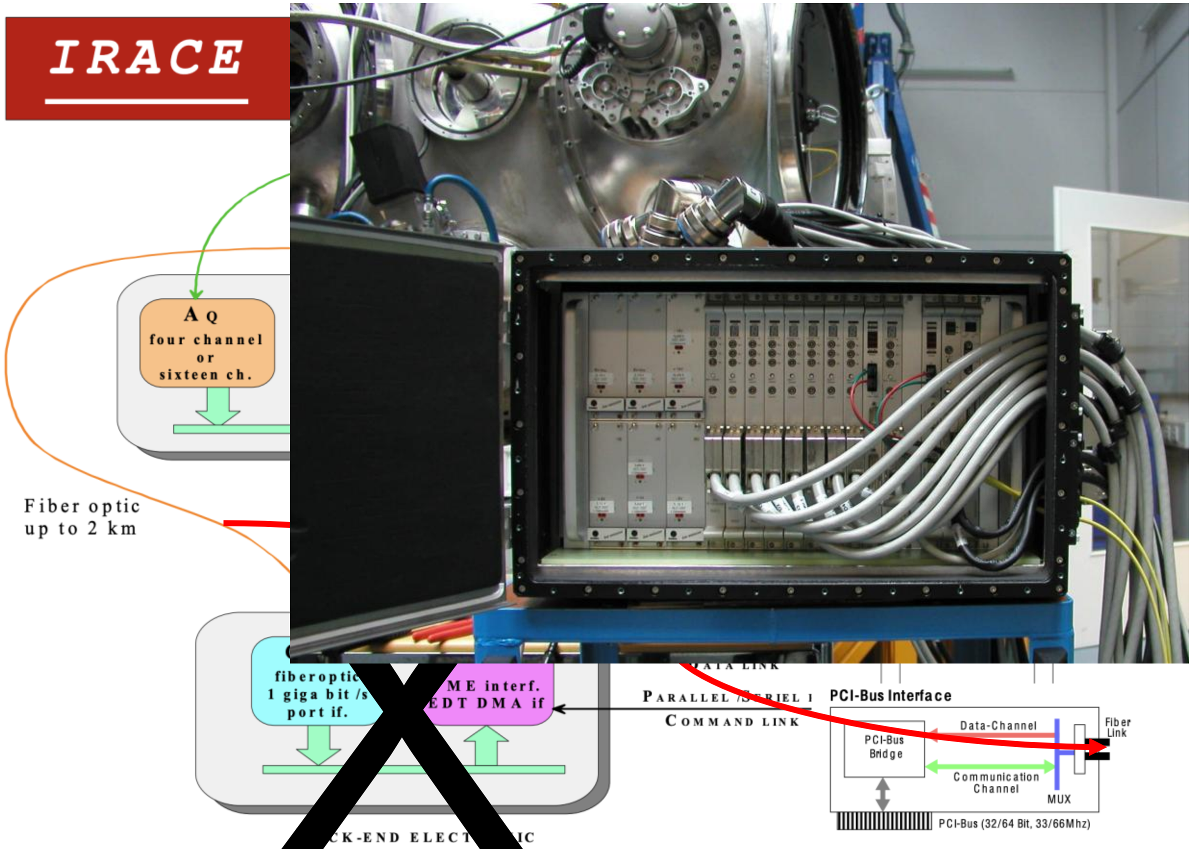


# Evolution of ESO Detector Controllers

**IRACE (Infrared Array Control Electronics)**
**(InfraRed Spectrum)**

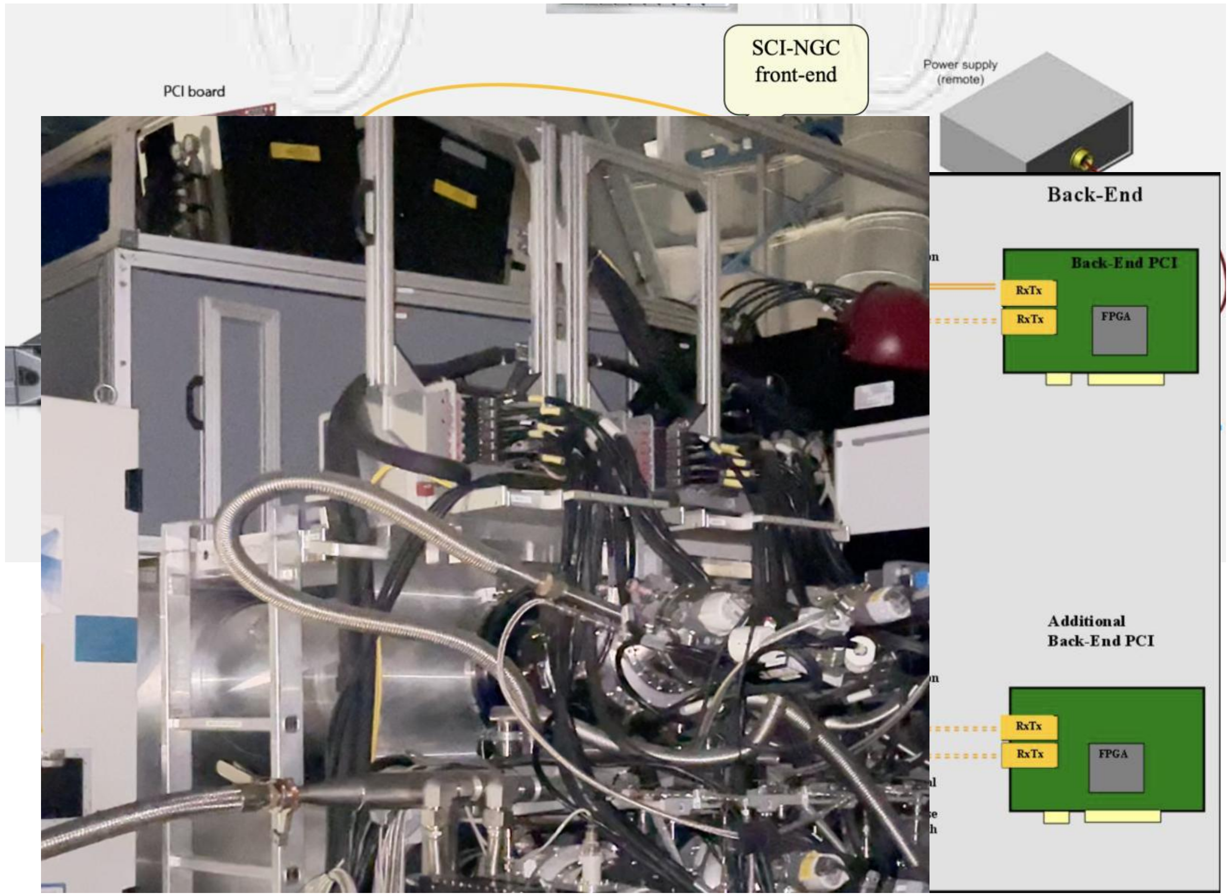
- The first IRACE prototype was successfully demonstrated in October 1996-1998. FPGA-based
- ESO developed a new generation IR detector controller VLT and La Silla Observatory
- Operated reliably for decades and still in use across multiple instruments (HAWKI, X-SHOOTER)



# Evolution of ESO Detector Controllers

**NGC** (**N**ew **G**eneral detector Controller

- After ~12 years (2008), both FIERA and IRACE are aging.
- The NGC controller is based on the Xilinx FPGA.
- The NGC controller is a modular, customizable system.
- For Optical and Infrared Astronomical Applications
- Operated reliably for 16 years across multiple instruments (KMOS, CRIRES+, SPHERE, etc.)

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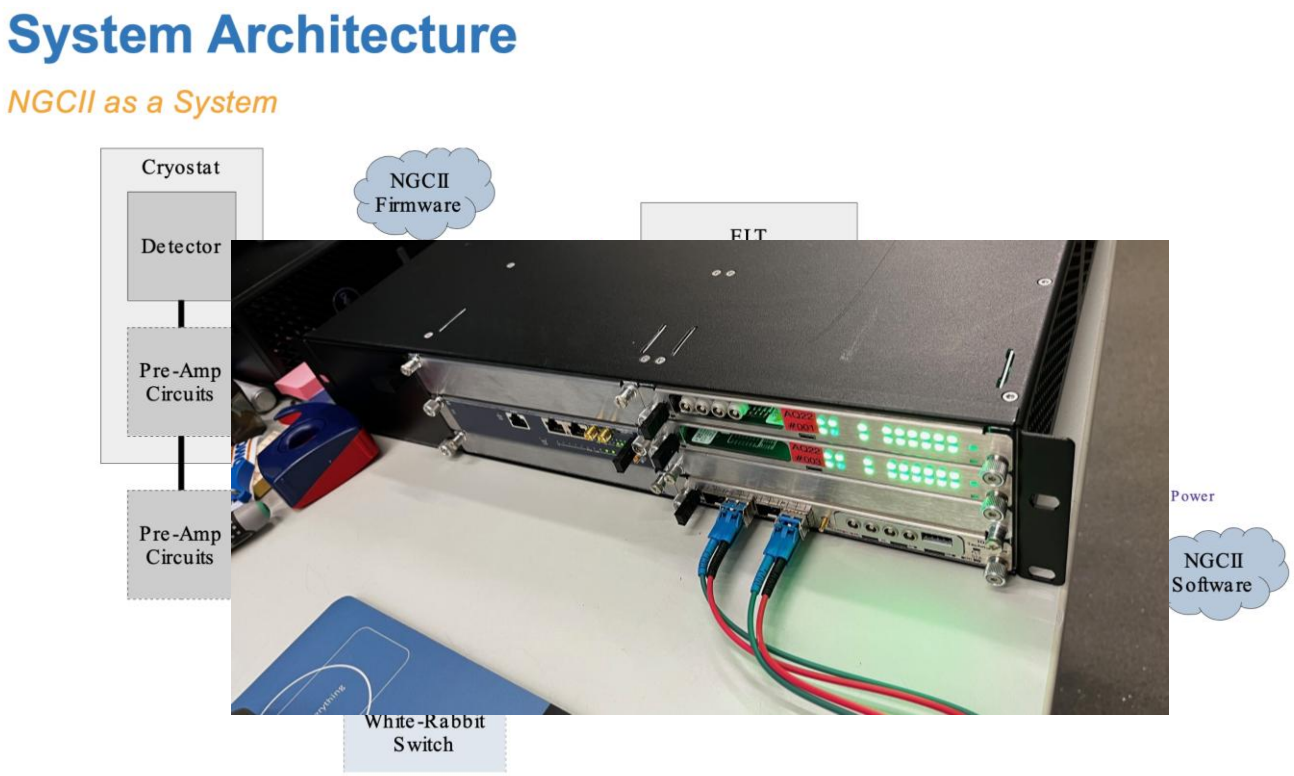
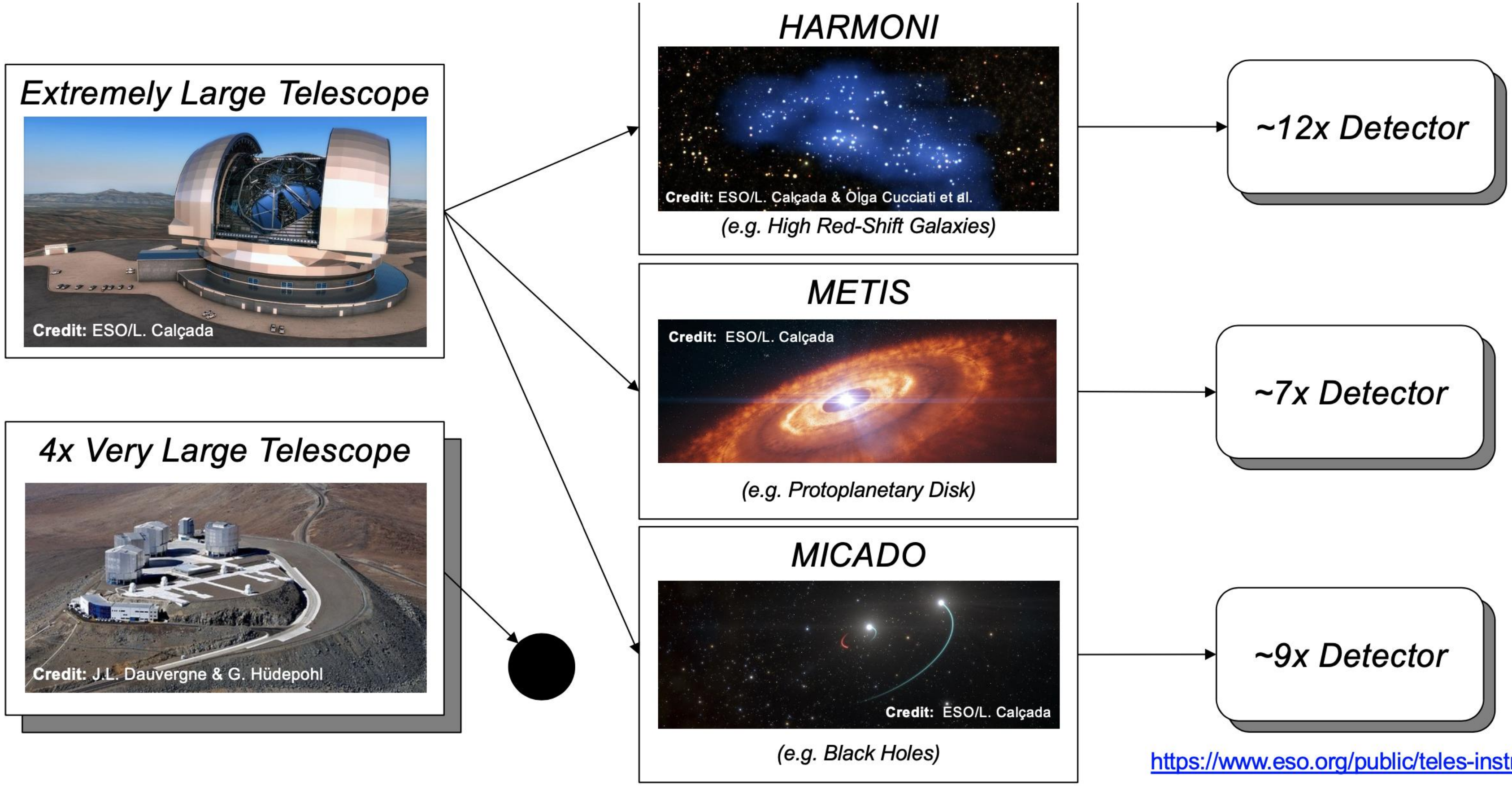
# Evolution of ESO Detector Controllers

NGC II (**N**ew **G**eneral detector **C**ontroller) Version **II**

- Project officially started in 2020. First light with the CMOS detector was achieved in summer 2023
- Covering ELT new requirements like, 10 Gb Ethernet, RTMS (MUDPI), PTP, time stamping, etc.
- Compatibility with the NGC, regarding detector readout files, like Clock pattern, Sequencer files, etc.
- High degree of modularity and flexibility (MicroTCA.4 standard)
- Compact size and low volume
- Synchronization of NGCII racks
- NGCII shall be able to readout all different types of detectors, with different readout speeds, number of output channels, etc.
- CMOS type detectors to be supported: Hawaii-2RG/4RG, SAPHIRA (32ch, 64ch) CCD type detectors to be supported: Teledyne e2v CCDs, CCD-231, CCD290-99, etc.



# Evolution of ESO Detector Controllers




https://www.eso.org/public/teles-instr/elt/instruments/

# Upgrade of the Detector Controller

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# Upgrade of the Detector Controller

- **Decades of Legacy :** NGC evolved from over 30 years of ESO controller technology (FIERA + IRACE).
- **Unified Platform :** NGC supports both optical and IR detectors, reducing system diversity.
- **Operational Risks :** Failures in obsolete systems can cause extended instrument downtime.
- **Training Efficiency :** Standardizing controllers reduces the learning curve for engineers and technicians.
- **Maintenance Simplification :** One spare part inventory for NGC instead of separate stocks for multiple platforms.
- **Future-Proofing :** Aligns detector control capabilities with new-generation instrument requirements.
- **Obsolescence Plan Alignment :** Supports the Observatory's long-term strategy to reduce outdated systems.
- **Next-Generation Integration :** NGC II is the baseline controller for upcoming VLT and ELT instruments, ensuring compatibility and performance.

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# Upgrade of the Detector Controller

**Strategic Focus with Universities**

**Main Goal**

- Create a cryogenics & detector lab at a Chilean university to support UVB/VIS cryostat upgrades for X-Shooter (or UVES) in 2 phases (4 years).
- Replace FIERA with NGC II and evaluate $LN_2$ → pulse tube cryocooler transition.

**Leverage Experience**

- Build on Paranal's FIERA→NGC test bench (E2V CCD 88-42).
- Training/workshops with Paranal Detector Group.
- ESO Garching visits: NGC II integration, detector testing, pulse tube cryocooler expertise.

**Innovation & Research**

- Optimize detector readout modes.
- Reduce readout noise (HW/FW).
- Improve reliability of vacuum sensors.

**Outcome :** Modernized UVB/VIS arms, reduced obsolescence, stronger national expertise in detectors & cryogenics.

# Upgrade of the Detector Controller

**Two-Phase Plan (4 Years) (Proposal)**

**Phase 1 (Years 1–2) – Laboratory Setup & Pilot**

- Establish cryogenics/detector lab with test bench modeled on Paranal FIERA→NGC using E2V CCD 88-42.
- Training & workshops from Paranal Detector Group; technical visit to ESO Garching for NGC II integration and Cryogenics Group pulse tube expertise.
- Pilot NGC II installation on UVB cryostat and initial pulse tube vs $LN_2$ evaluation.
- Begin research on readout mode optimization, readout noise reduction, and vacuum sensor reliability.

**Phase 2 (Years 3–4) – Migration & Optimization**

- Apply lessons from UVB to migrate VIS cryostat to NGC II.
- Install and test pulse tube on VIS cryostat with Garching Cryogenics Group methods.
- Deliver ESO-led university seminars/courses; finalize upgrades on both cryostats.

# Detector Laboratory - Paranal

# Connect with ESO

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# Thank you!

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