# AST3-NIR camera for the AST3-3/ AST3-4 telescope for the Kunlun Infrared Sky Survey (KISS)


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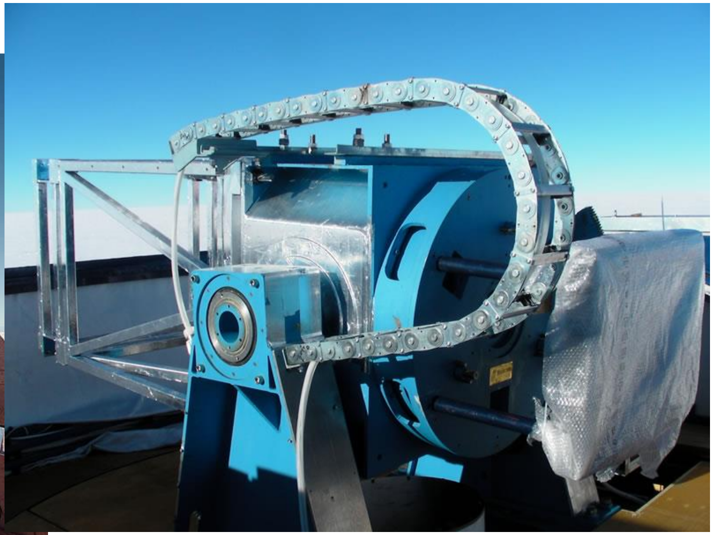
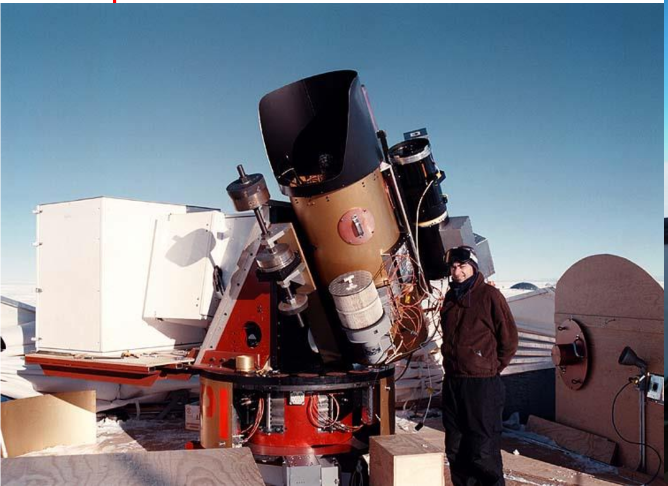
# Existing/past facilities

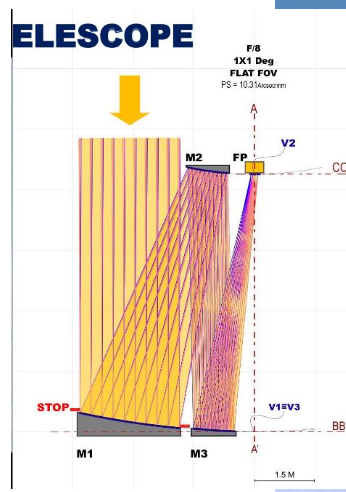
- Site testing instruments at South Pole, Dome C, Dome A, Ridge A, Dome F including sky cameras
- SPIREX 0.6 metre near infrared telescope at South Pole
- IRAIT: 0.8 m infrared telescope at Dome C
- ASTEP: 0.4 m telescope at Dome C
- CSTAR: 3x 0.2 m telescope at Dome A
- AST3: 0.5 m at Dome A

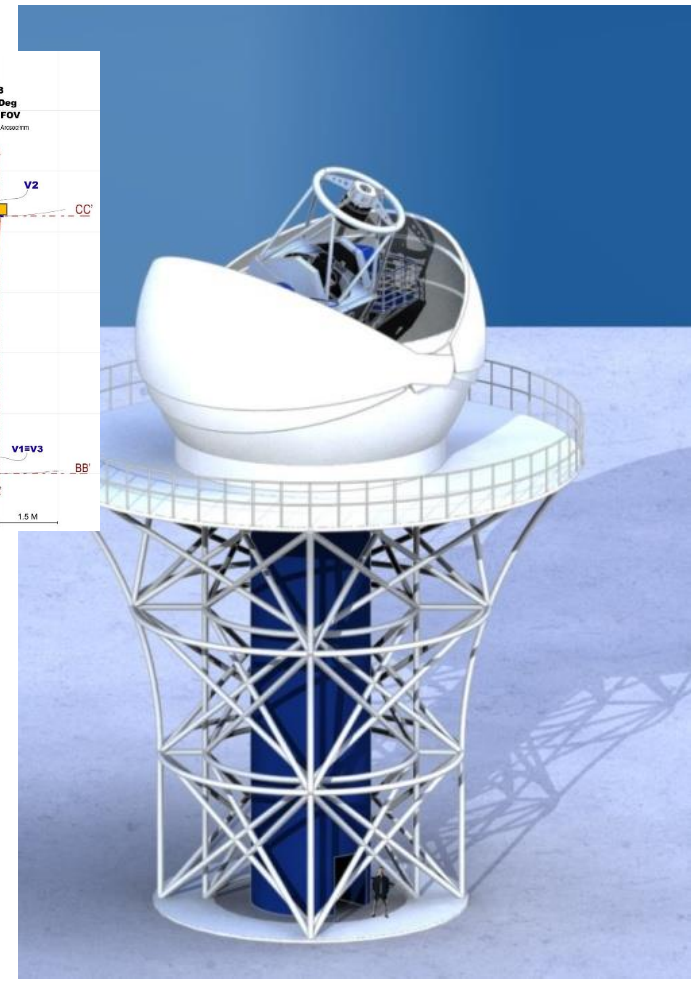


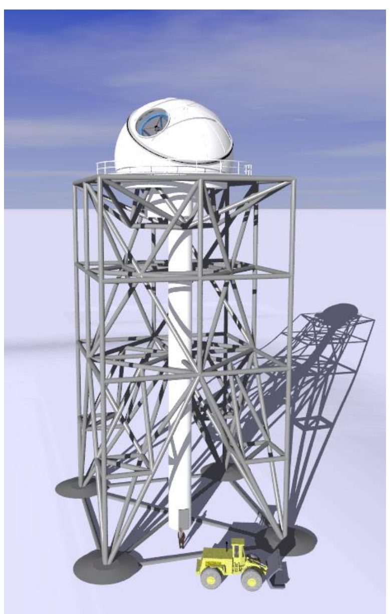


# What's next?

- AIRO: 2 metre  class South Pole telescope
- DMT: 2.5 metre Dome C telescope
- PILOT: 2.5 metre Dome C telescope
- PLT: 2.5 metre Dome C telescope
- ACWI: 2 metre South Pole telescope
- JDFT: 2 metre Dome F telescope
- KDUST: 2.5 metre Dome A telescope





# AST3-NIR and KISS

- AST3-NIR is a version of AST3 dedicated to conduct the KISS infrared sky survey at Kdark.
- Instrument concept initially developed during *China-Australia Symposium: Astronomy and Astrophysics* in Nanjing in Dec 2013.
- Technical concept developed during early 2014.
- China responsible for telescope hardware and control, logistics, deployment.
- Australia responsible for instrument hardware and control, and power generation system.
- Science and operations joint responsibility.
- Grant submission April 2014 for camera (PI Jeremy Mould) and successful Nov 2015.
- AST3-3 telescope already funded, AST3-4 telescope pending
- Project Kick-off meeting tomorrow

# Science

- **Supernovae:** provide infrared coverage for skymapper optical discoveries and provide independent detections
- **Supernovae in starburst galaxies:** very high sensitivity measurements to detect SNe in bright extincted nuclei of ULIRG
- **Exoplanets:** transiting and secondary transit planets particularly hot Jupiters
- **Variable stars:** stellar evolution via studies of Miras in the Magellanic clouds
- **Synoptic universe:** use reverberation mapping to characterise the dust around nearby AGN
- **Gamma-ray bursts:** search for high luminosity distant GRB afterglows
- **YSO variability:** transient survey of high dust extincted clusters within molecular clouds
- **Young massive stars:** searches for transiting massive stars within star forming stellar clusters
- **Cosmic infrared background:** will provide a higher accuracy than 2MASS due to lower thermal background

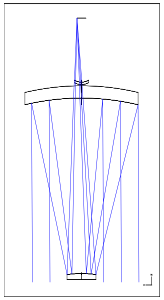
# Key parameters

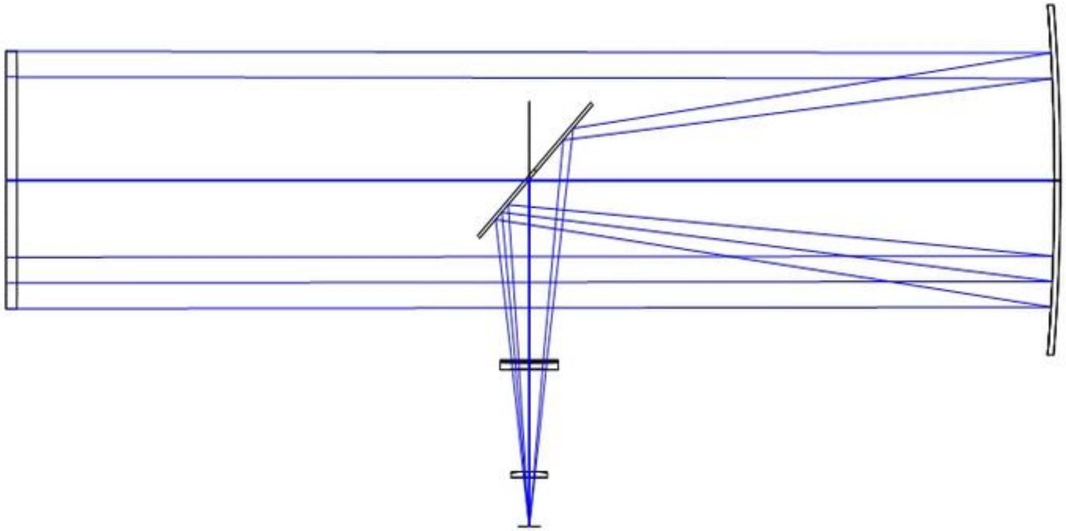
- Wavelength range: Kdark window (nominally λ=2.36 μm with Δλ=0.18 μm) only
  - The complexity of the Dewar is significantly reduced relative to multi-λ instrument.
  - Telescope tube can be sealed as transmissive glass of appropriate diameter is available at 2.4 μm.
  - Kdark provides the largest sensitivity gain from the Antarctic site.
- Primary mirror diameter: 680 mm
  - Consistent with the size of the existing AST3-1 and AST3-2 mirrors and may allow elements of the telescope structure to be identical.
  - Cost not prohibitive.
- Image quality: diffraction limited (within 10%)
- Detector Array: 2kx2k near infrared array with 18 micron pixels
  - Commercially available at reasonable cost
  - Descope to 1kx1k may be required
- Spatial sampling/FOV: Spatial sampling on the detector shall sample the telescope delivered image quality diameter across 2 pixels
  - Sampling in the range 0.85-1” per pixel (f/5.5-6.4), giving a field-of-view~ 30’ x 30’. As the instrument will be background limited there is no point in undersampling the psf to get a wider FOV.

# Optical Design

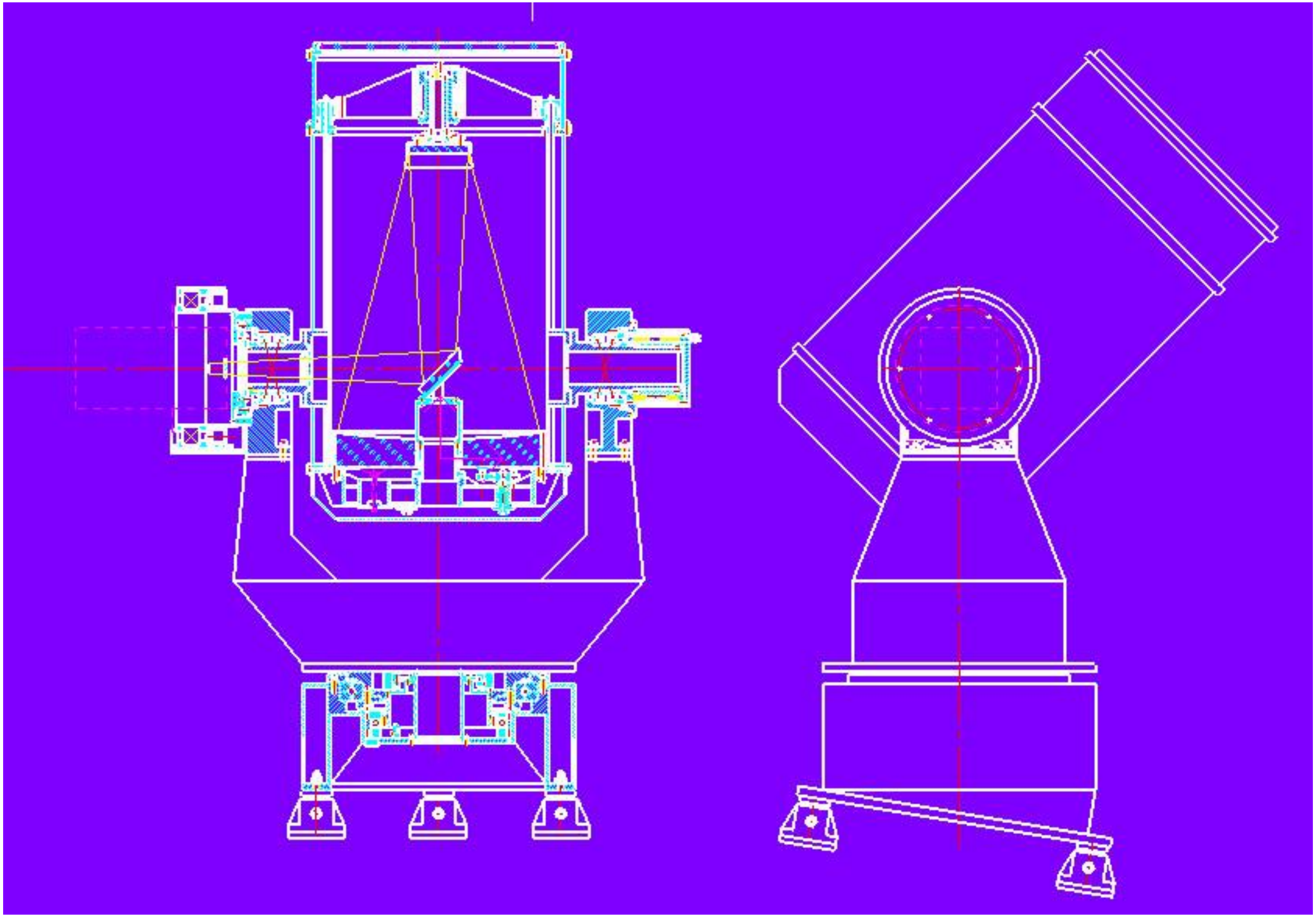
- Optical design: Ritchey–Chrétien (or similar Cassegrain variant) consisting of a primary and secondary mirror with a single (preferred) corrector lens followed by a filter in front of the detector array.
  - *This is a relatively compact and simple design that should achieve the required image quality.*

- Telescope options: either use existing AST3-3 (designed for optical) or new design optimized for NIR with Cassegrain focus (AST3-4).



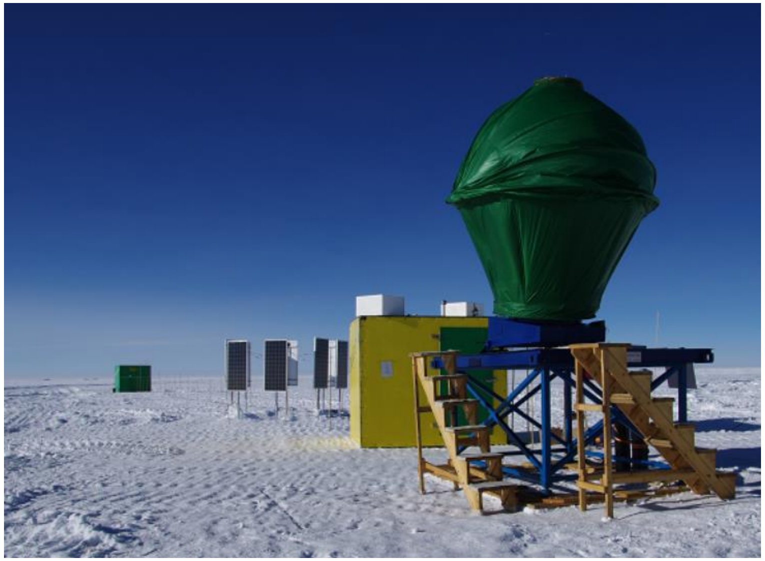


# Optomechanical design



# Environmental protection

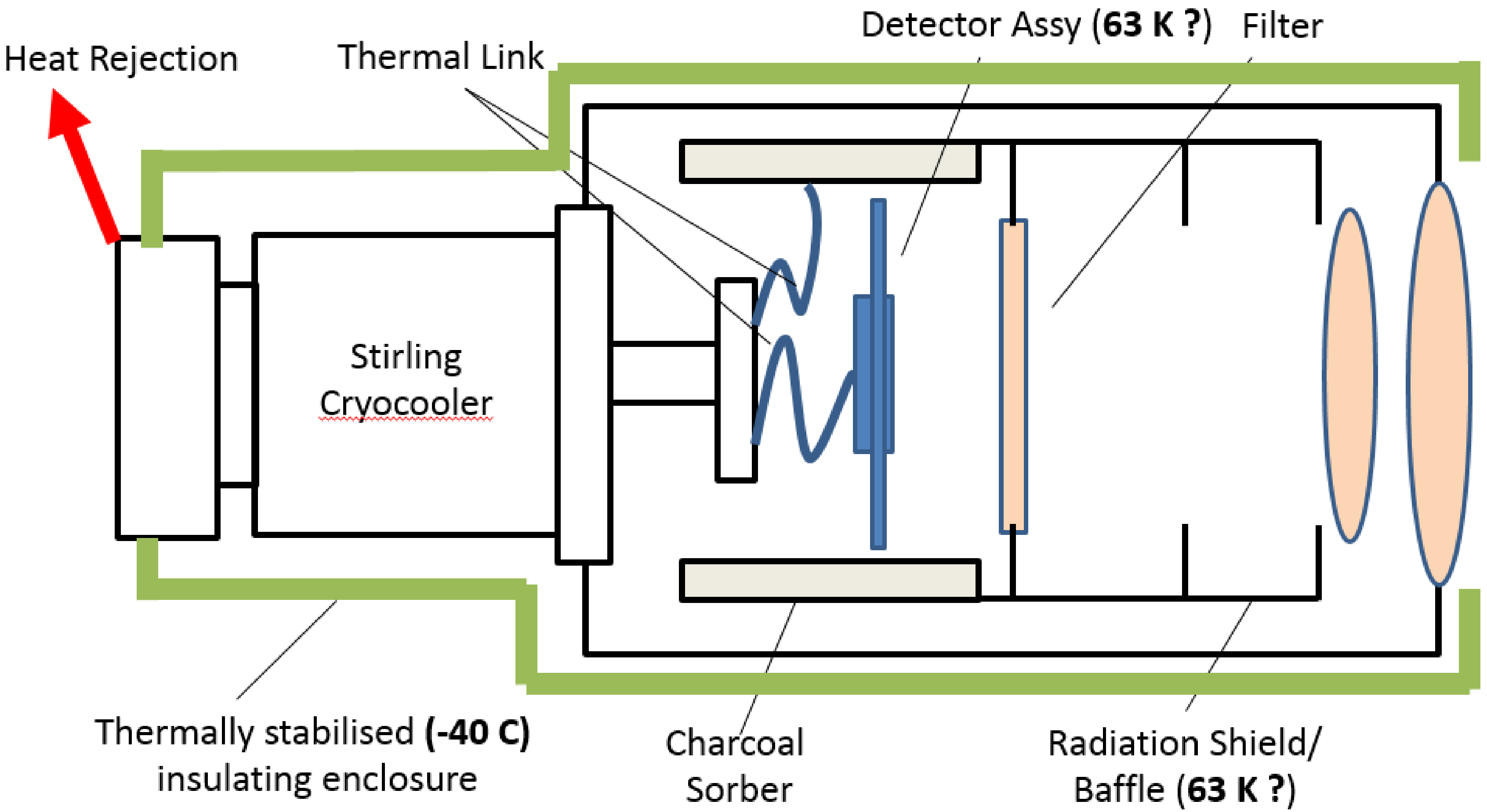
- The telescope tube including the primary and secondary mirror shall be sealed from the external environment using a window placed above the secondary mirror and a seal placed at the instrument flange.
  - *Protection from snow and ice accumulation on the primary and secondary mirrors.*
- The telescope enclosure shall be filled with dry nitrogen with dessicant.
  - *To ensure low water vapour content. Possibly the tube can be over-pressure.*
- Air within the telescope enclosure shall be left to track external ambient temperature.
  - *The telescope enclosure will not be heated to avoid issues with turbulence generation.*
- Heaters shall be provided
  - *To sublimate ice as a back-up in case it forms.*
- The telescope front window shall have an ITO coating (or similar) that allows it to be heated to several degrees above ambient temperature.
  - *Required to prevent ice accumulation on the window front surface and to sublimate ice if it does form.*



# Instrument Configuration

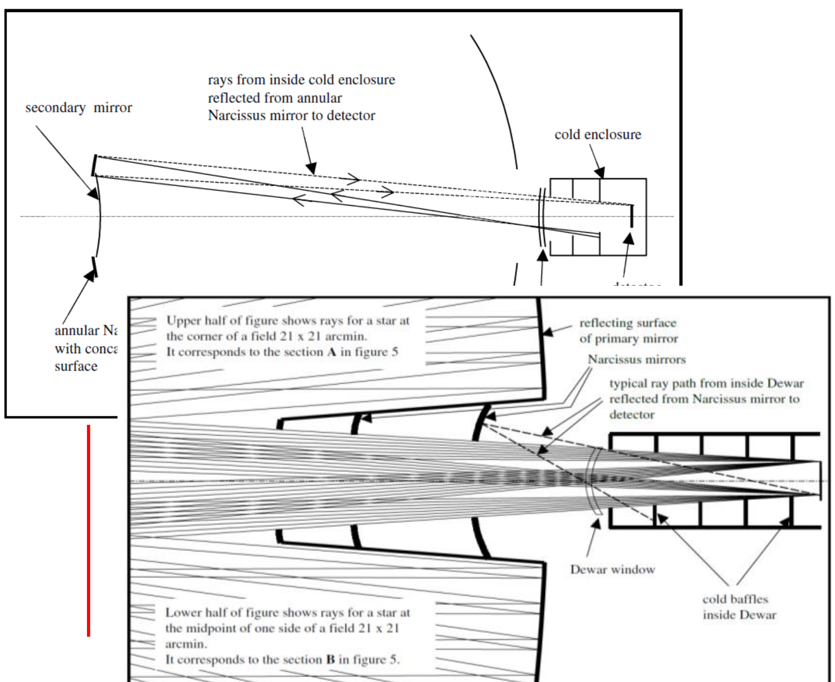
- The instrument shall consist of a Dewar that houses the final corrector lens as a window, the cold baffles, filter, detector, and associated cryogenic subsystems.
- The instrument Dewar internal components (including the filter, the baffles, and the detector) shall be maintained to a temperature low enough so that detector dark current does not dominate over the sky background.
  - *Likely to be ~50 photons/pixel/second, which is well above the minimum achievable with H2RG (1e-3 e-/pix/s). This will impact decision of whether 2.5 or 5µm cut-off chips are used and provides a bench-mark for the alternative detector suppliers.*
- The instrument Dewar shall hold its required vacuum for at least 12 months, with a preference for several years.
  - *This is likely problematic to achieve with the off-the-shelf Teledyne Dewar.*

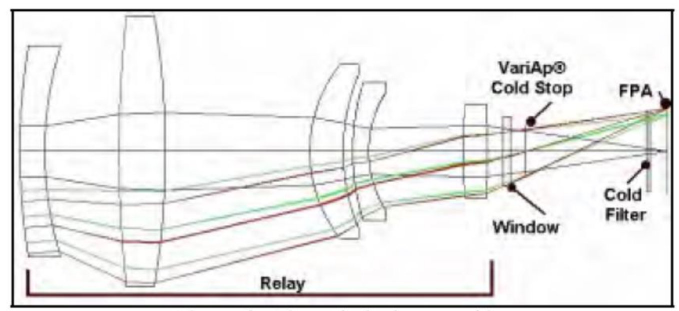
# Instrument Concept



# Thermal emission

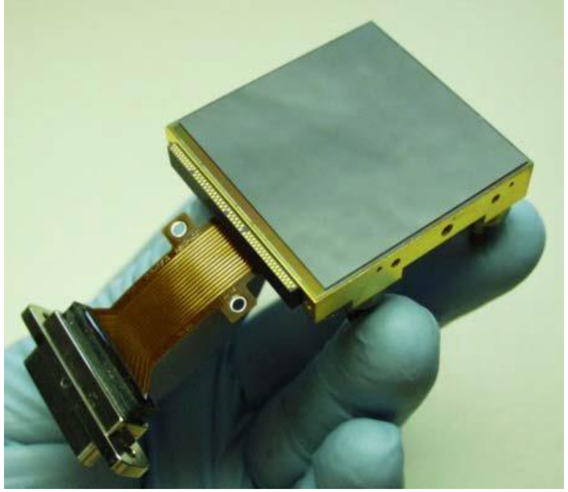
- Narcissus mirrors around the telescope primary mirror cavity, secondary mirror support, and fold mirror (if installed), and cold baffles within the instrument Dewar will be used to reduce thermal emission seen by the detector array.
  - *This option removes the need for a cold stop and hence intermediate focus within the instrument Dewar.*
- Alternative is cold stop within the instrument Dewar
  - *Design and Implementation of instrument is more complex and expensive*

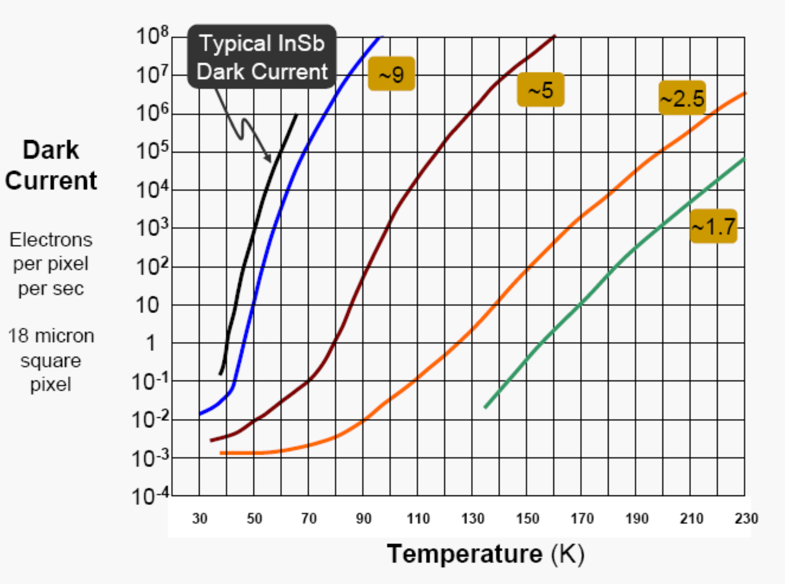


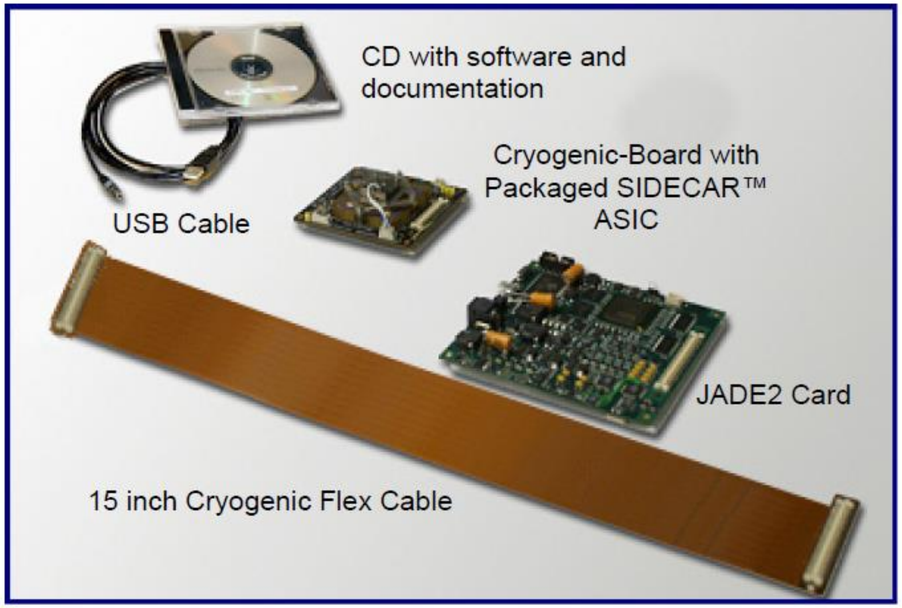



# Detector array

- Concept design and costing based on using the HAWAII 2RG MCT array from Teledyne.
- Chips available with off-the-shelf controller.
- Well characterised dark current versus temperature, read noise and QE.
- 1RG fits same package
- ITAR restrictions apply to US export

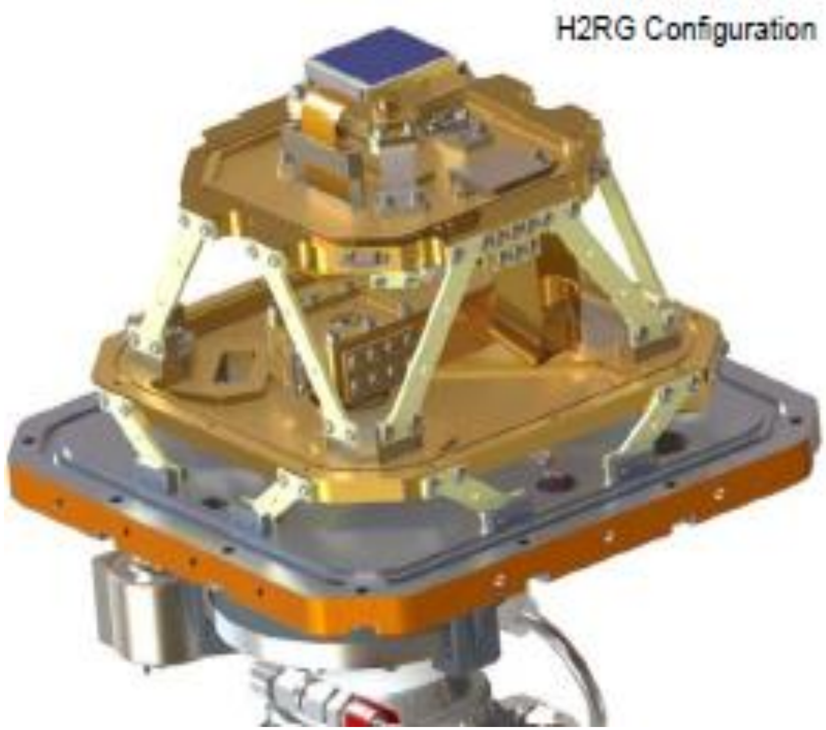




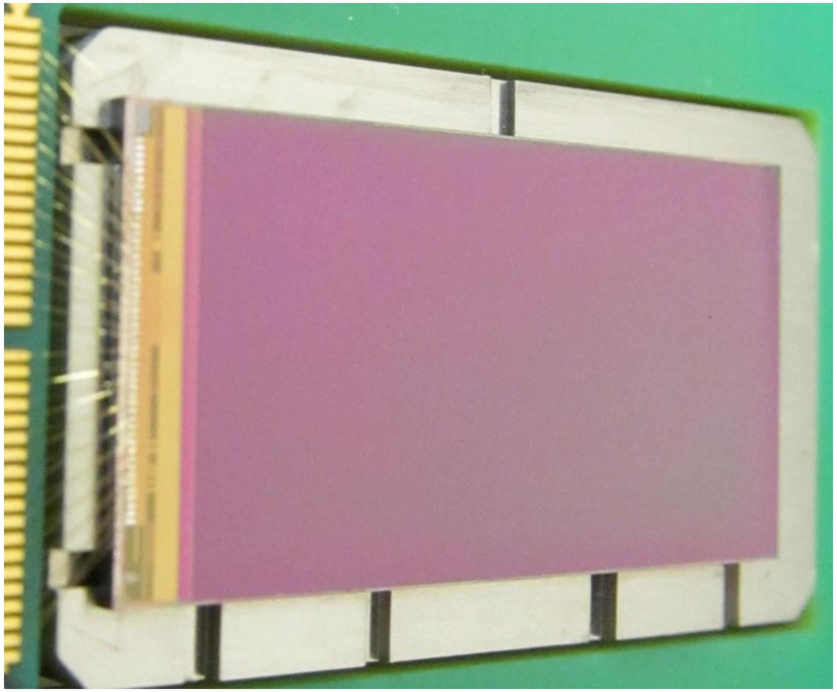
# Dewar design

- Teledyne also can supply Dewar with integrated Sunpower cryo-cooler (subcontracted to GL Scientific).
- Likely issues with vacuum hold-time and winterisation of electronics
- In instrument concept will use chip plus controller and detector assembly plate.
- Vacuum vessel and temperature controller to be redesigned in-house (AAO).

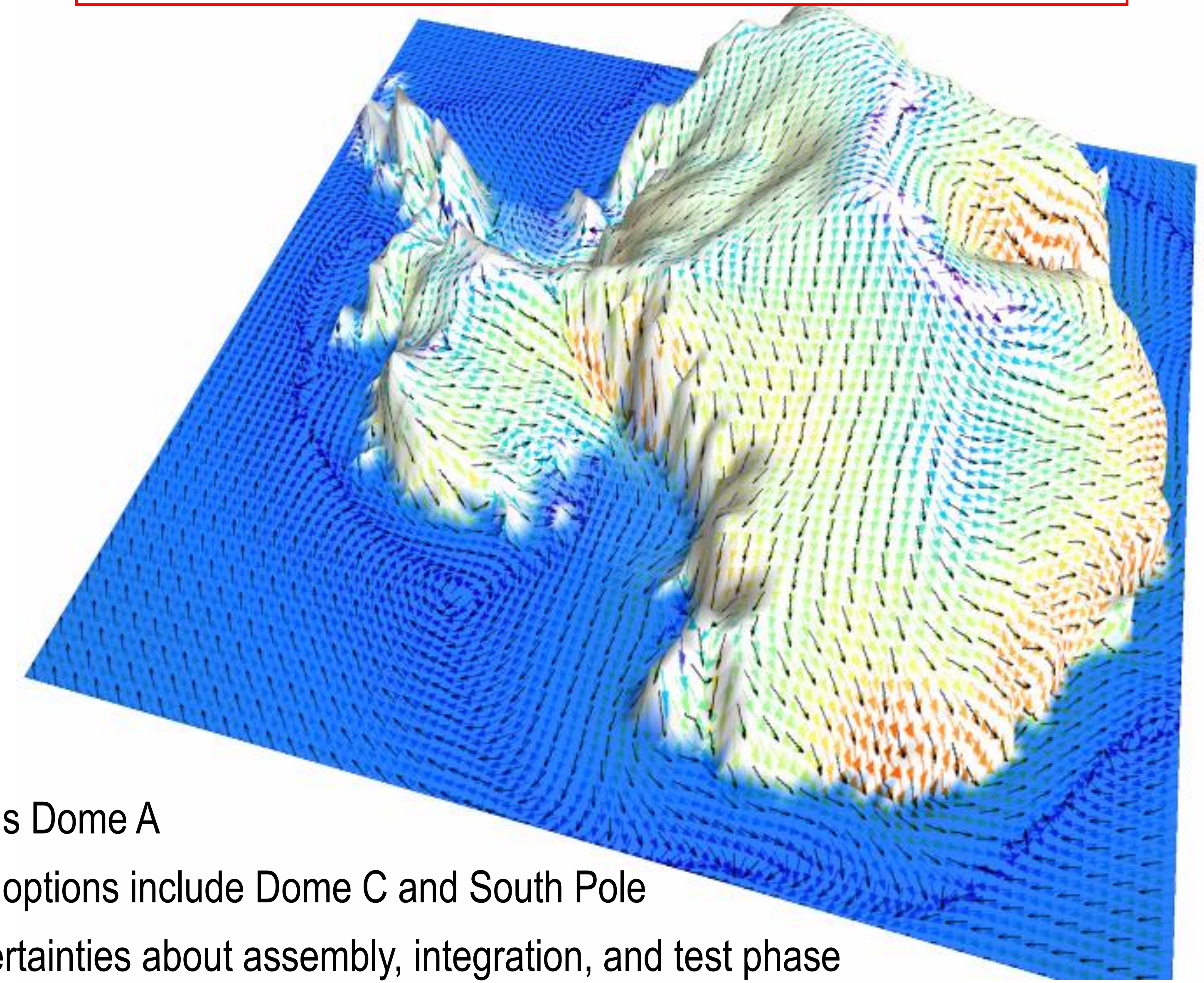



# Alternative detector suppliers

- US ITAR restrictions may make procurement for instrument delivered to China problematic
- Australian export control regulations
- Alternative suppliers of infrared arrays are being investigated.
- E.g., Selex ES 1920x1080p 12 μm pitch MCT array.



# Location



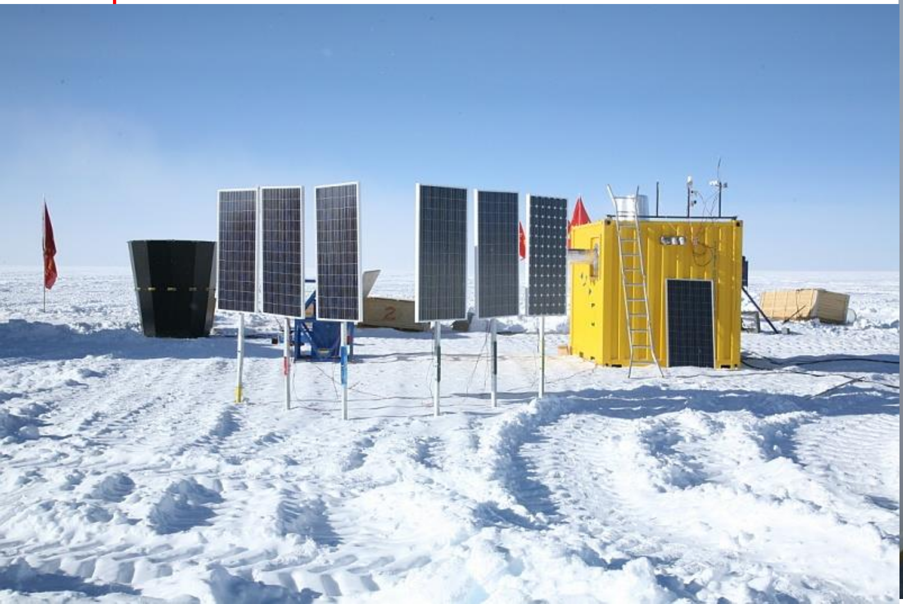
- Baseline is Dome A
- Fall-back options include Dome C and South Pole
- Also uncertainties about assembly, integration, and test phase

# Operation and control

- Similar to AST3-1 and AST3-2 will be operated fully remotely
- Requires careful engineering:
  - MTBF analysis
  - AIT phase
  - Commissioning schedule
  - Redundancies throughout system (particularly instrument control hardware and telescope control hardware)
  - Data pipeline must include on-site reduction (as long delay between data collection and full availability)
  - Data security and storage

# How is it powered?

- PLATO modules for power supply have proven extremely reliable
- PLATO for AST3-NIR requires few kW
- Replication of existing system non-ideal rather requires significant upgrade to the power capabilities
- Larger (multi-cylinders?) engines
- Larger solar panel array
- Higher fuel capacity

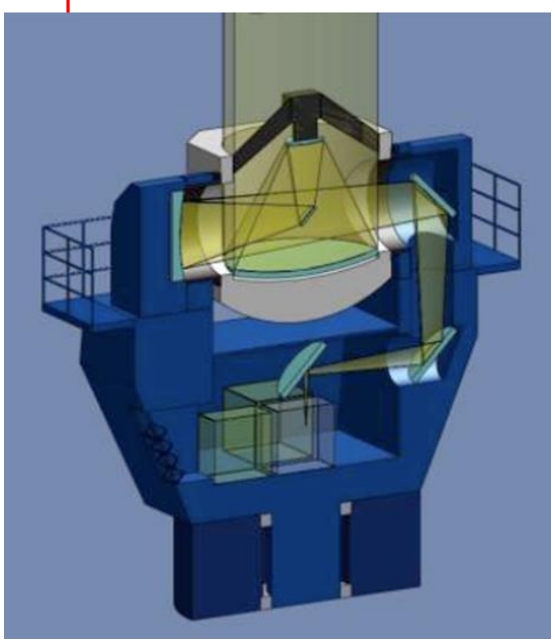


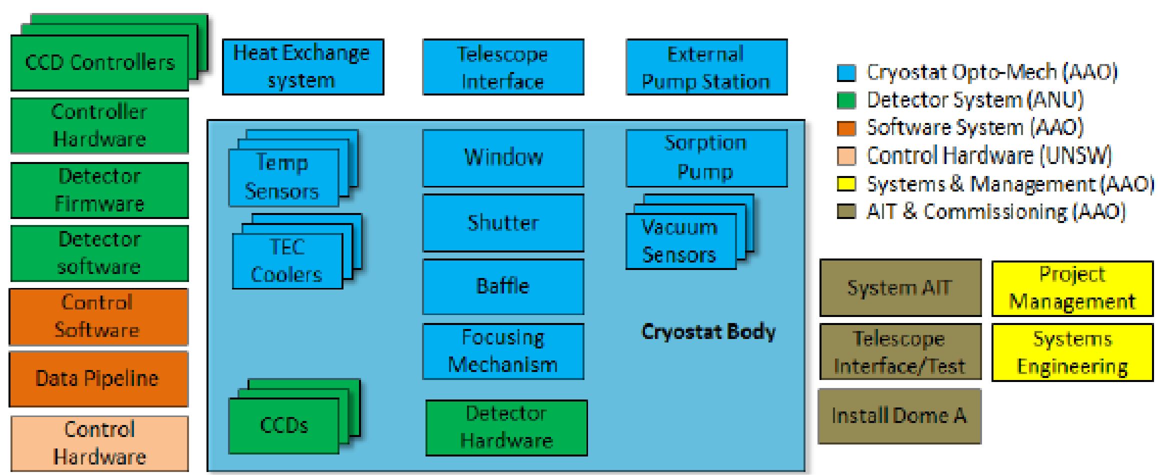
# Schedule

| ID | Milestone Completion | Due Date |
|---|---|---|
| 0 | Preliminary discussions with DoS re: ITAR | January 2015 |
| 1 | Project Kick-off (Meeting in Nanjing) | March 2015 |
| 2 | Requirements Review | June 2015 |
| 3 | Detector & Interface Specification | July 2015 |
| 4 | RFQ Teledyne | August 2015 |
| 5 | Contract Negotiation (Detector) | September 2015 |
| 6 | Purchase Order (Detector) | October 2015 |
| 7 | FDR (De-Scope Option) | December 2015 |
| 8 | SAIL Readiness Review at SUT | July 2016 |
| 9 | Procurement Lead-time (Detector) | November 2016 |
| 10 | Float Procurement Lead-time (Detector) | January 2017 |
| 11 | AIT | Feb. – June 2017 |
| *N/A* | *Schedule Float* | *~4 months* |
| 12 | Camera Pre Delivery Review | Late 2017 |
| 13 | Shipping to Antarctica | Nov. 2017 |
| 14 | Commissioning | Jan. 2018 |
| 15 | Science Survey commences | Feb. 2018 |

# KDUST: instrumentation

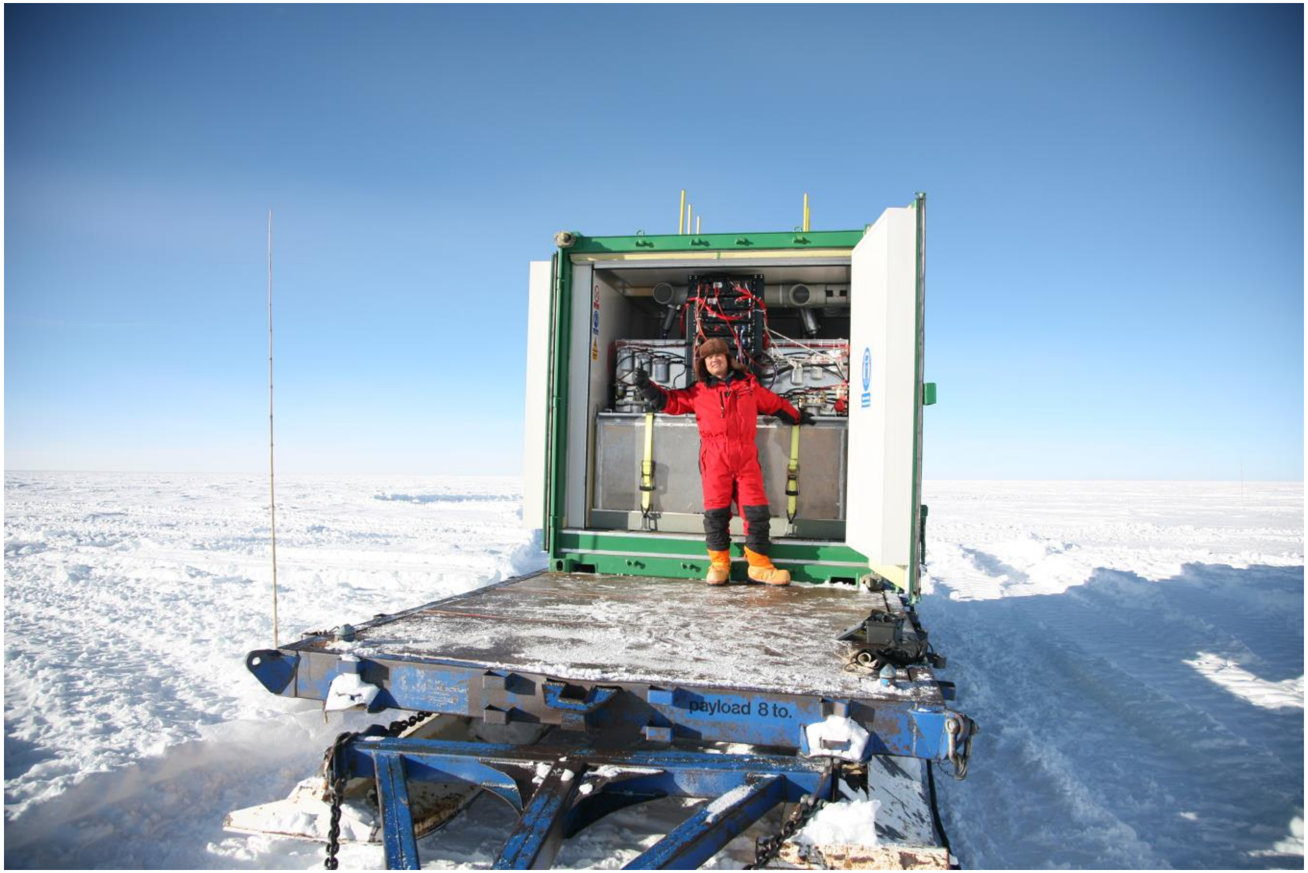
- 1. KDUST instrumentation:
  - Chinese institutes (NIAOT) have a well advanced concept for KDUST telescope
  - Australian consortium AAO, UNSW, ANU responded to call for proposal for the design and construction of the KDUST optical camera
  - Australian institutes have shown interest in developing designs for an infrared instrument for KDUST
  - Natural extension of AST3-NIR





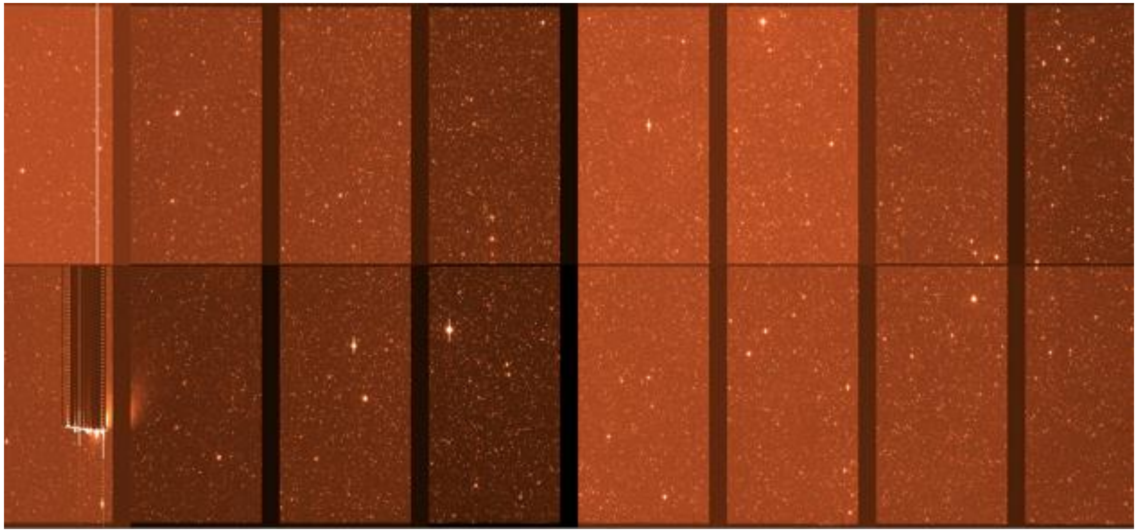
# KDUST: power supply and control

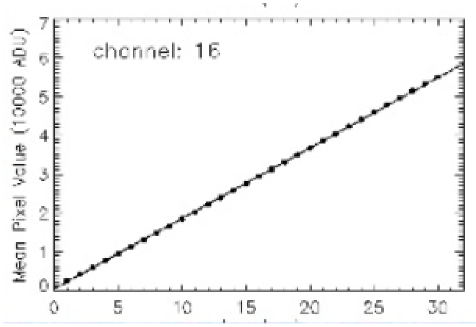
- 2. KDUST power supply:
  - KDUST will require 10s of kW
  - AST3-NIR requirements are step towards this



# KDUST: science

- 3. KDUST science:
  - Four science working groups formed as part of AAL-DBRCAS on AST3 collaboration: SNe and GRBs, synoptic universe, exoplanets, variable stars
  - Significant interest from the Australian astronomical community
  - Similar model expanded for AST3-NIR
  - Similar model should work for KDUST





# Summary

- **Thanks to the low ambient temperature at Dome A and the low background sky radiation at K dark,  a very simple telescope and infrared Dewar (without the need for a cold stop, which would require additional optics) can compete very strongly as a wide field near infrared survey instrument.**
- **AST3-NIR would be the first such instrument.**

- **AST3-NIR is also a good opportunity for enhancing the collaboration and for developing the technology.**