



# Near-Infrared Tip-Tilt Sensor Preliminary Design Review

WMKO: Peter Wizinowich, Andrew Cooper, Mike Hess, Ean James,  
Sudha LaVen, Jim Lyke, Chris Neyman, Thomas Stalcup  
Caltech: Roger Smith, Randy Bartos, John Cromer, Richard Dekany,  
David Hale, Gustavo Rahmer  
Microgate: Roberto Biasi, Mario Andrighttoni, Dietrich Pescoller  
Flat Wavefronts: Marcos van Dam

KAON 863  
April 25, 2011

# Agenda

- 12:00 PDT. Introduction (Wizinowich – where not otherwise noted)
- 12:10 Response to SDR Reviewer Committee Report
- 12:30 Requirements, Interfaces & Compliance
- 12:40 Opto-Mechanical System
- 13:00 Camera System (Smith)
- 13:30 Real-Time Control System (Biasi)
- 13:50 Controls System
- *14:10 Break*
- 14:30 O OCD & Operations Software (Neyman)
- 15:00 Assembly, Integration & Test
- 15:20 Project Management
- 16:00 Discussion + Q&A (Boyer)
- *16:20 Break*
- 16:30 Reviewer Discussion (Boyer)
- 17:30 Reviewer Report (Boyer)
- 18:00 End



# Introductions

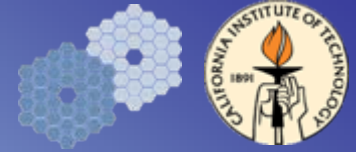
## Reviewers:

- Antonin Bouchez (GMT AO Lead)
- Corinne Boyer (TMT AO Lead – chair)
- Randy Campbell (WMKO AO Operations Manager)

## Team & Contributors (to date)

- PI & Project Manager: Peter Wizinowich (WMKO)
- Project Scientist & Team: Tommaso Treu (UCSB), Mark Morris (UCLA), Liz McGrath (UCSC)
- Camera Lead: Roger Smith (COO)
- WMKO Engineers: Andrew Cooper (EE), Mike Hess (ME), Ean James (ME), Sudha LaVen (SE), Jim Lyke (SA), Chris Neyman (systems), Thomas Stalcup (OE)
- Caltech Engineers: Randy Bartos (ME), John Cromer (SE), Richard Dekany (systems), David Hale (SE), Gustavo Rahmer (EE)
- Microgate: Roberto Biasi, Mario Andrighettoni, Dietrich Pescoller
- Performance Analysis: Marcos van Dam (Flat Wavefronts)





# Response to SDR Review Committee Report

Peter Wizinowich  
WMKO

# Executive Summary Response

“some aspects ... that should be further developed”

- “Expected system performance under the full range of operational conditions including the continued need for visible guide stars”
  - The recommended analysis was not performed. For cost reasons we do not intend to follow through on this recommendation.
  - A modest amount of additional modeling performed by van Dam with GMT funding during the PD; no WMKO budget to proceed further.
  - An AO operations team effort to characterize the LBWFS performance was begun but has stalled. See slide 15.
- “Component requirements flow down and interfaces”
  - System requirements flow down to functional requirement documented in requirements spreadsheet (KAON 835).
  - Initial attempt to flow down “WFE budget” in KAON 835 (see tab of that name). Also in throughput & emissivity spreadsheet
  - The interfaces are defined in the Microgate SOW (KAON 824), the camera to AO ICD (KAON 836) & the keyword interface spreadsheet (KAON 857)
- “More reasonable contingency by Preliminary Design Review”
  - The contingency was increased from 3% at SDR to 10.6% at PDR due to additional WMKO funds. Due to PD phase cost overruns the current level of contingency is not believed to be adequate.



# Scientific & Technical Requirements Status Response 1

- “Develop requirement 4: ... define the measurement precision and accuracy needed ... under various operational conditions.”
  - Not addressed (for cost reasons there are no plans to address this).
- “The motivations to use simultaneously the Near-Infrared Tip-Tilt Sensor and the existing STRAP system ... We recommend considering descoping this capability.”
  - Descoped to a goal.
- “Consider descoping requirement 9 (only one Tip-Tilt Guide Star).”
  - This was already a goal (not a requirement).



# Scientific & Technical Requirements Status Response 2

## Scientific & Technical Requirements Status

- “Develop the operation concept document to better define the calibration, acquisition and dithering requirements including the software requirements.”
  - Done (KAON 859) & used to define the operations software.
- “A requirement should be added that the Near-Infrared Tip-Tilt Sensor ... is serviceable while in position, or that the unit can be removed for service and re-installed without realignment.”
  - Requirement added. Supported by design, including camera reinstallation without realignment if necessary.
- “The wavefront error budget requirements should flow down into subsystem requirements.”
  - The elements that impact the error budget were identified but the budget was not flowed down. Not currently planning to do more given the cost constraints.





# System Design Status Response 1

- “... concerned that the Low Bandwidth WFS performance on faint stars might limit the system performance ... We recommend that the Low Bandwidth WFS performance model be validated against Keck’s operation experience.”
  - Agreed that this needed to be done, but outside the NIR TTS budget. Operations group setup to characterize LBWFS performance & to ensure 5x5 mode operation, however no significant progress to date. See slide 15.
- “Particular care should be given to access ... as well as thermal dissipation and vibration.”
  - Access was considered carefully in developing the SolidWorks model. Thermal dissipation addressed with a thermally insulated camera controller & locating most heat sources in the AO electronics room. Vibration addressed with choice of Polycold cooler & design of components.
- “... team is proposing to study some alternative options to the current optical design to reduce the number of elements, to simplify alignment and hopefully to reduce the cost.”
  - The PDR design is slightly simpler (1 less optic & fewer different glasses).





# System Design Status Response 2

- “We support the team’s effort to make the design consistent with the future addition of a Tip-Tilt mirror.”
  - An appropriate tip-tilt mirror was included in the PDR SolidWorks model.
- The operation of the Near-Infrared Tip-Tilt Sensor in it’s various modes ... needs to be developed during Preliminary Design.”
  - Done.
- “... the interface issues will need significant development during Preliminary Design ...”
  - Done.



# Risks & Mitigation Strategies Response

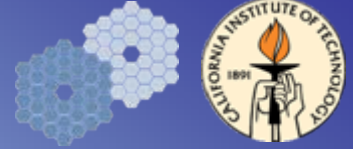
- “... we endorse the plan to perform laboratory tests of the detector ROI (self heating) and of the RTC interface during the preliminary design phase.”
  - Self heating test completed. Not an issue. Documentation pending.
  - RTC interface issues resolved with ARC. Camera data emulator under development & to be shipped in May to Microgate.
- “The greatest risk ... lack of adequate contingency... We strongly recommend ... significant reductions in scope, or seek assurance that the observatory or partners will cover the potential overrun.”
  - Observatory provided an additional \$240k after SDR. Descope proved to be necessary in preparing PDR SEMP
- “... we see a potential for lack of availability of key personnel.”
  - Adequately addressed during PD phase & looks viable for DD.
- “... the use of a low vibration “Cryo-Tiger” ... may have implications related to the placement of the compressor... The risk of this issue should be fully retired during Preliminary Design.”
  - This issue was fully addressed during PD with the choice to locate the compressor in the AO electronics room.



# Management Plan Response

- “We recommend building some contingency directly in the preliminary design schedule.”
  - PDR delayed from March 23 to April 25 however some DD work begun
- “The proposed plan to increase back the contingency to a more acceptable level should be more aggressive and descopes of requirements and or goals should be made.”
  - Solution provided by additional Observatory funds after the SDR. Ended up having to make additional descopes prior to PDR. Still an issue.
- “We recommend making sure that the team members are not overcommitted.”
  - Generally ok during PD except for initial ramp-up issues.
- “... camera would have significant capability for use as a science instrument... this option should be considered for a possible upgrade”
  - This was considered & remains a possibility, however no changes were made to the requirements or design to accommodate this future option.





# Requirements, Interfaces & Compliance

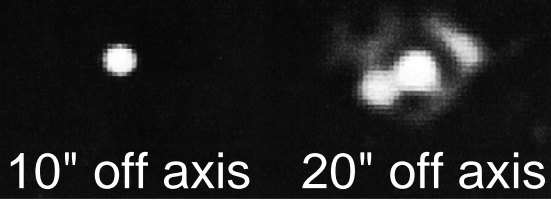
Peter Wizinowich  
WMKO

# Configuration Controlled Requirements & Interfaces

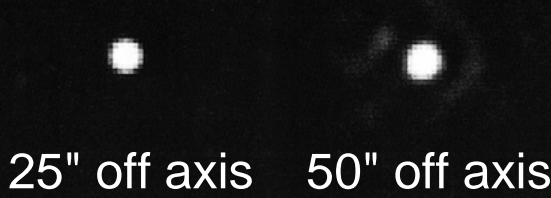
- [KAON 824](#): Microgate Statement of Work
  - Defines RTC requirements & interfaces (Keywords in KAON 857)
- [KAON 835](#): System & Functional Requirements Spreadsheet
  - Defines system-level requirements
  - Defines functional requirements for 4 of 5 subsystems
  - Current compliance documented for each requirement
  - System-level requirements documented in [KAON 823](#) along with tie to science requirements
- [KAON 836](#): Camera to AO Interface Control Document
  - Defines all interfaces to camera (keywords in KAON 857)
- [KAON 857](#): Keywords Interface Spreadsheet
  - Defines all keywords to be used to interface between subsystems & external to the NIR TTS system
- Configuration Control
  - Changes are tracked in each of these documents
  - Project manager approves changes to KAON 824, 835 & 836
  - LaVen maintains KAON 857



$r_0 = 15 \text{ cm}; \theta_0 = 1.3''$



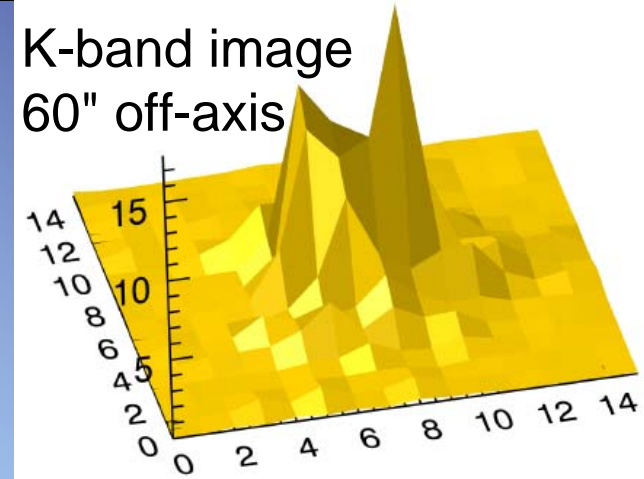
$r_0 = 18 \text{ cm}; \theta_0 = 3''$



# Performance Analysis

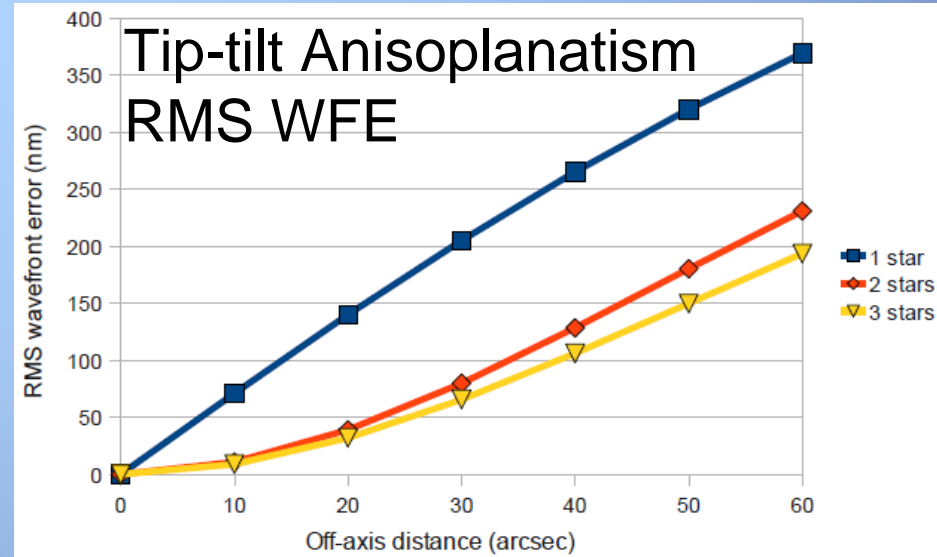
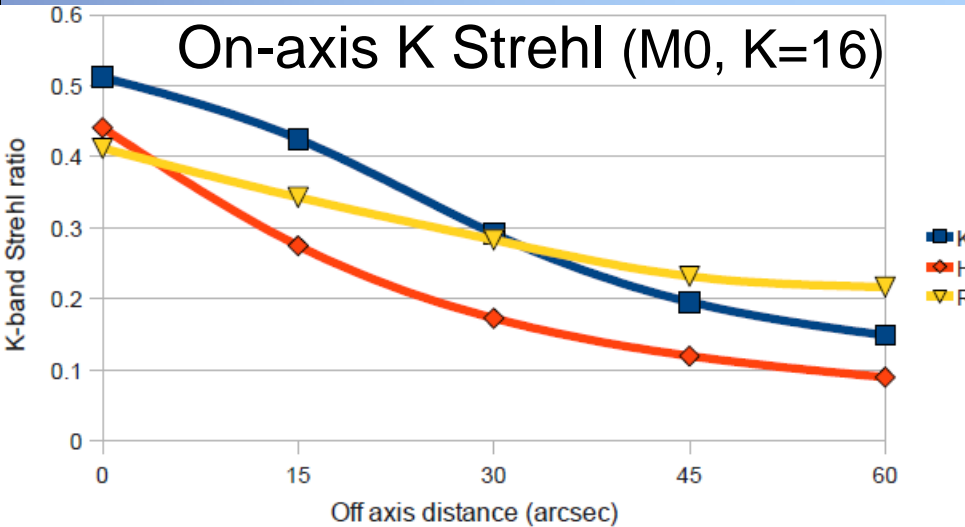
Median Mauna Kea  
isoplanatic angle =  $2.7''$

K-band image  
60'' off-axis



Van Dam 2011

$\lambda = 1.45 \mu\text{m}, D = 8 \text{ m}$   
Sandler et al. 1994



$100 \text{ nm} \rightarrow \text{SR}(K) = 0.92$





# Reviewer Topics

2) LBWFS performance on faint stars might limit the overall system performance

- Describe plans to address the issue during the next phase

Response:

- The LBWFS should not limit the NIR TTS performance
  - For a  $K = 16$  M0 star  $\rightarrow R = 18.5$  (or for  $H = 16 \rightarrow R = 18$ )
  - Currently use STRAP/LBWFS stars as faint as 19.2 (up to 72" off-axis) for 20x20 mode
- Team (Campbell, Kassis, Martin, Stomski) setup by Campbell & Wizinowich in January to address a number of LBWFS issues. Overall goals:
  - Ensure that the 5x5 LBWFS mode of the LBWFS is fully operational.
  - Identify & as agreed implement software or operational changes to improve LBWFS performance &/or observing efficiency.
  - Provide automated tools &/or user documentation recommending which mode, integration time & gain should be used as a function of guide star R magnitude.
  - Update the AO user information as appropriate.
- 1<sup>st</sup> suggestion was to measure & document the LBWFS performance vs R magnitude for both the 20x20 & 5x5 modes.
- Progress has been very slow (at least partly due to higher priorities).
- At minimum Campbell & Wizinowich plan to push on characterizing the 20x20 performance.
  - May utilize Panteleeva who is finishing up a NIRC2 throughput analysis based on archival data. May utilize Liu's brown dwarf binary data set.



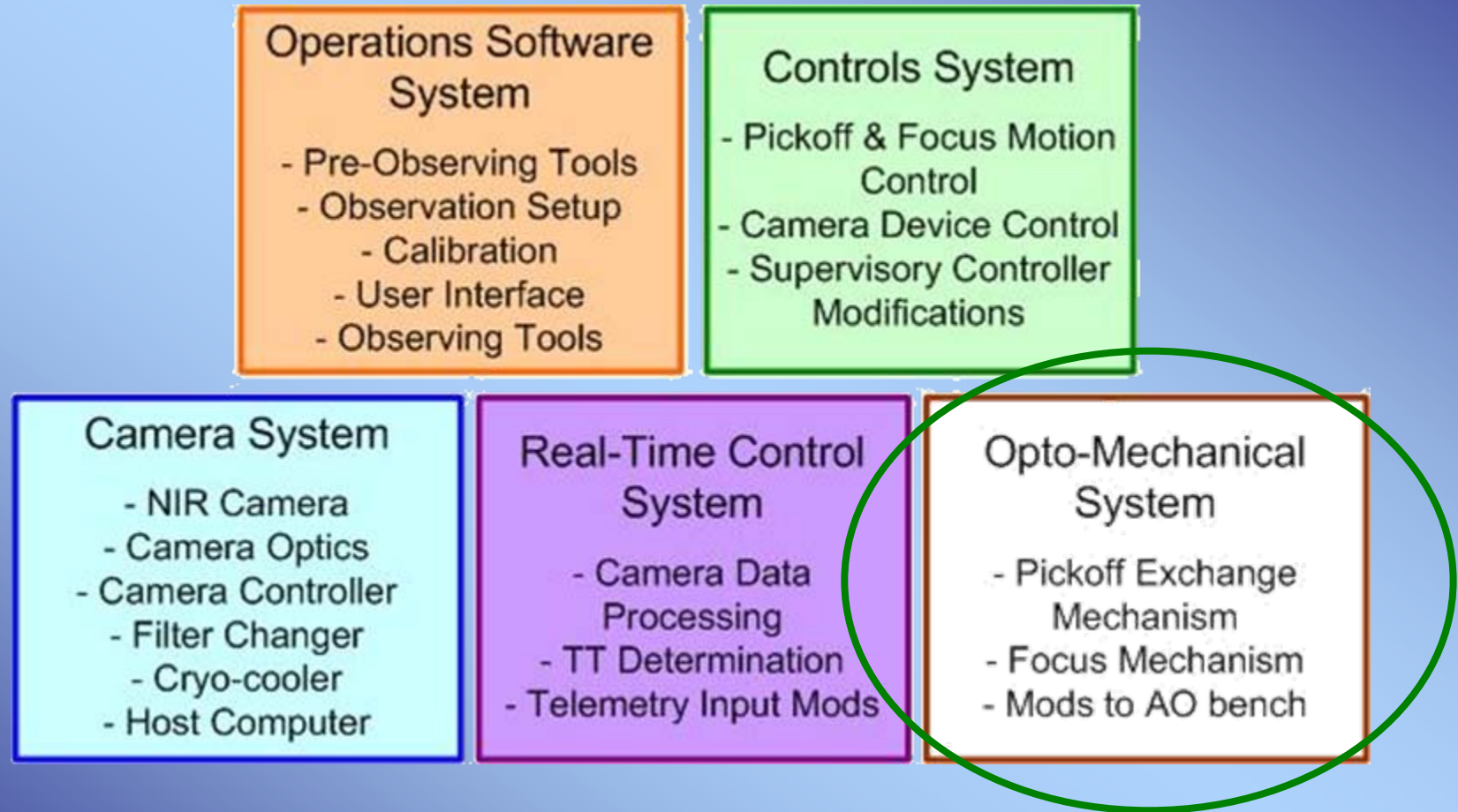




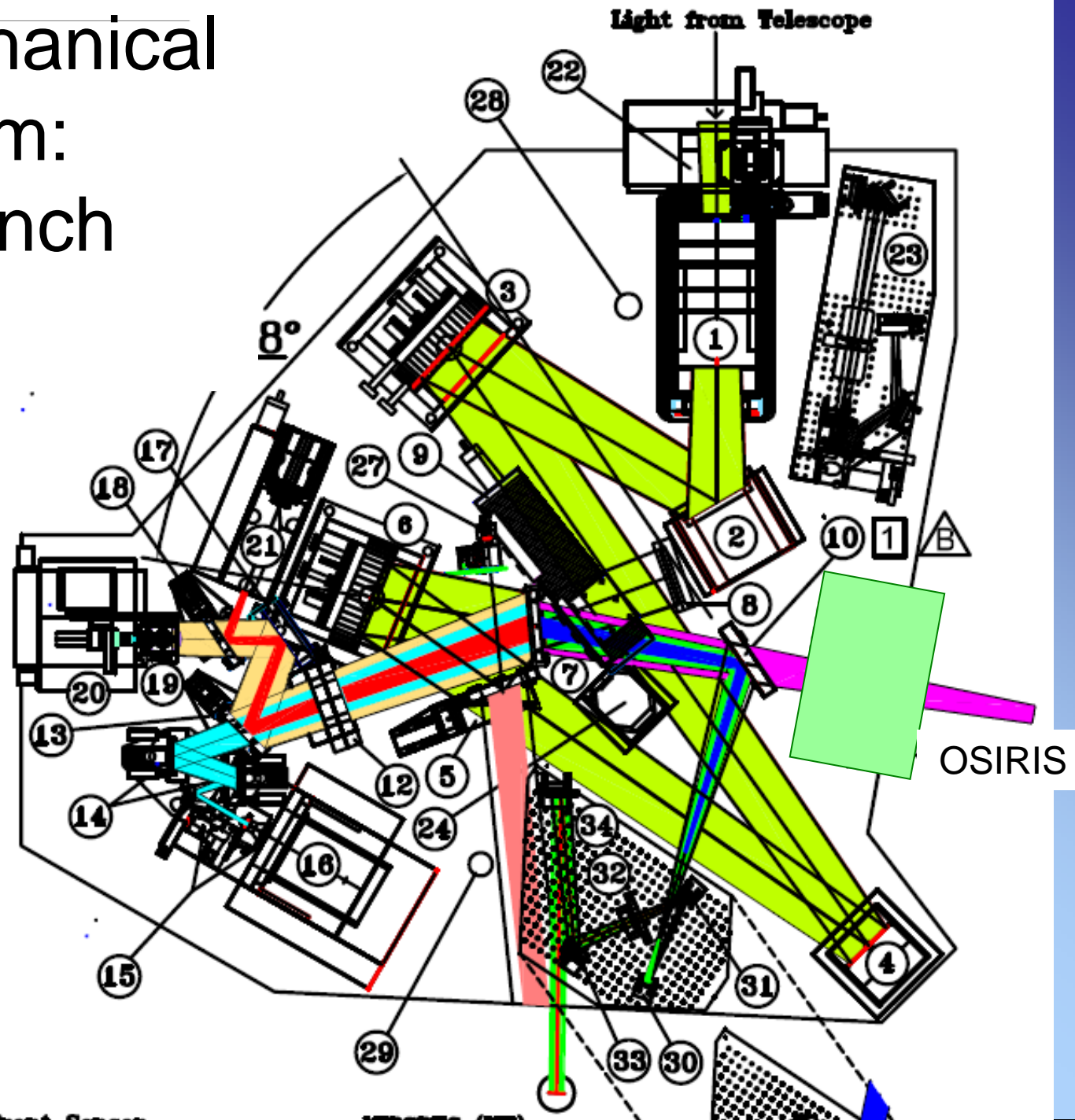
# Opto-Mechanical System Design

Peter Wizinowich  
WMKO

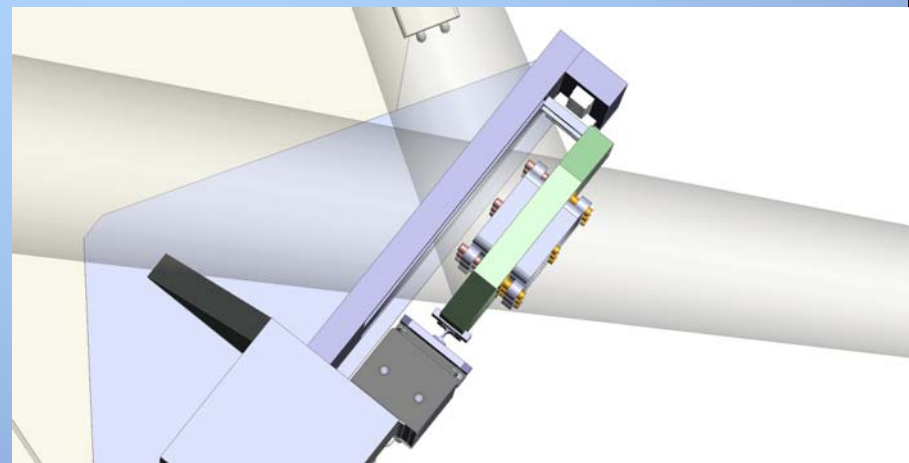
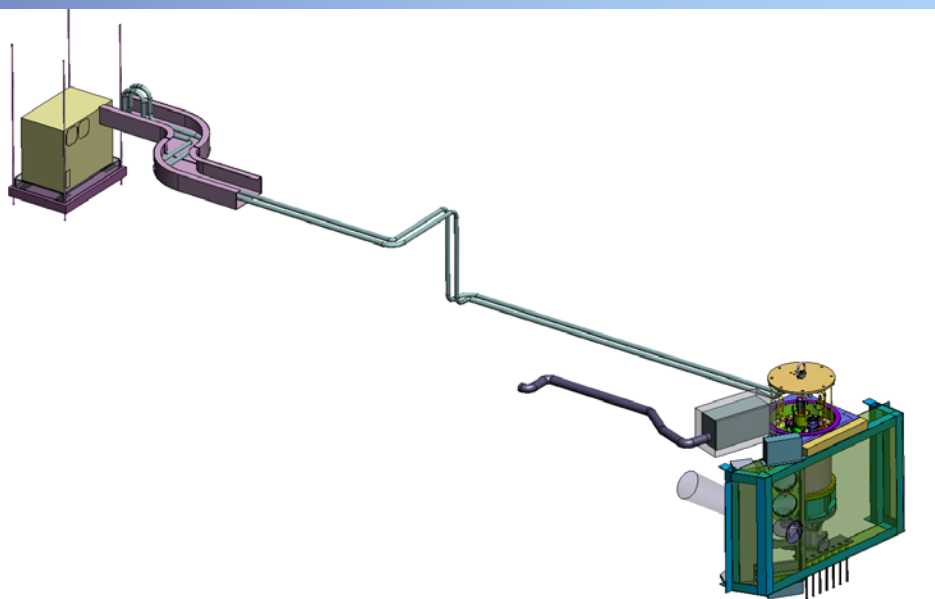
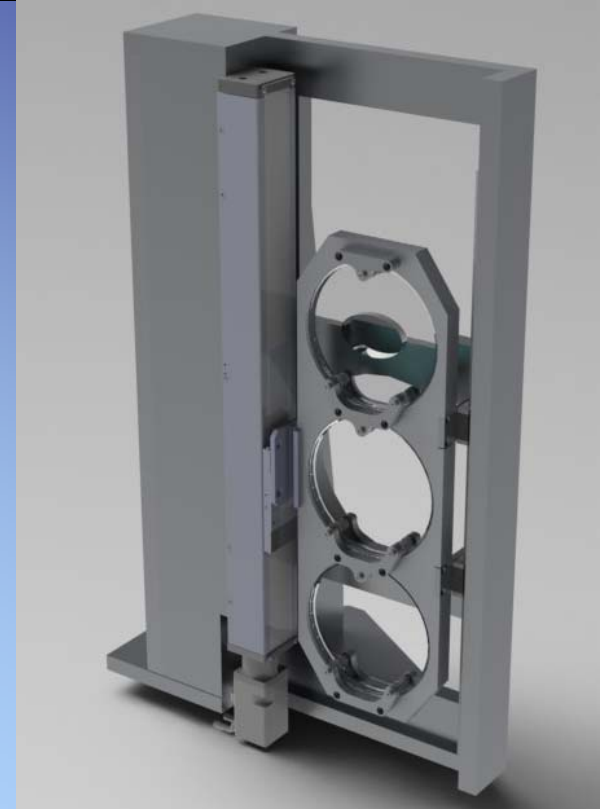
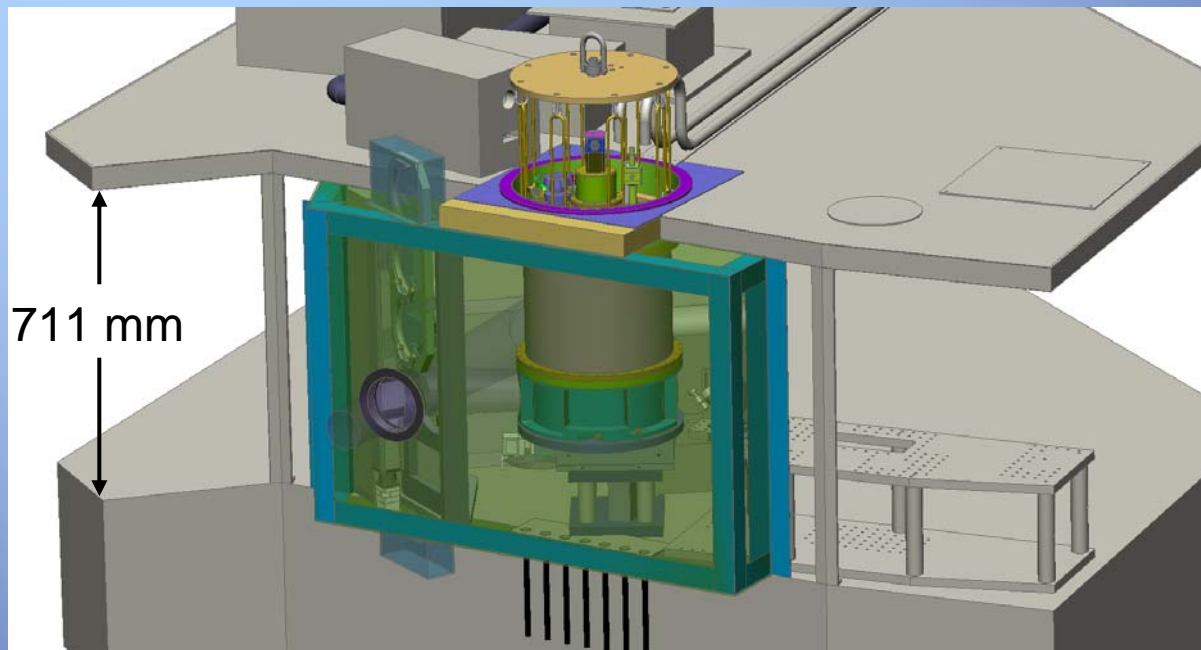
# Design Overview - Subsystems



# Opto-Mechanical System: AO Bench

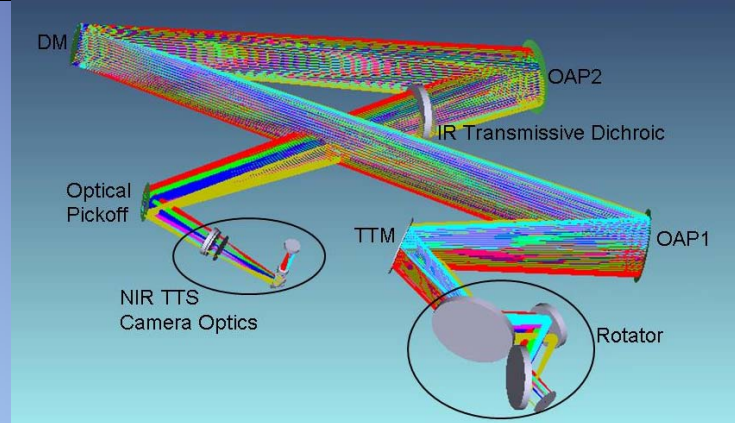


# Opto-Mechanical System

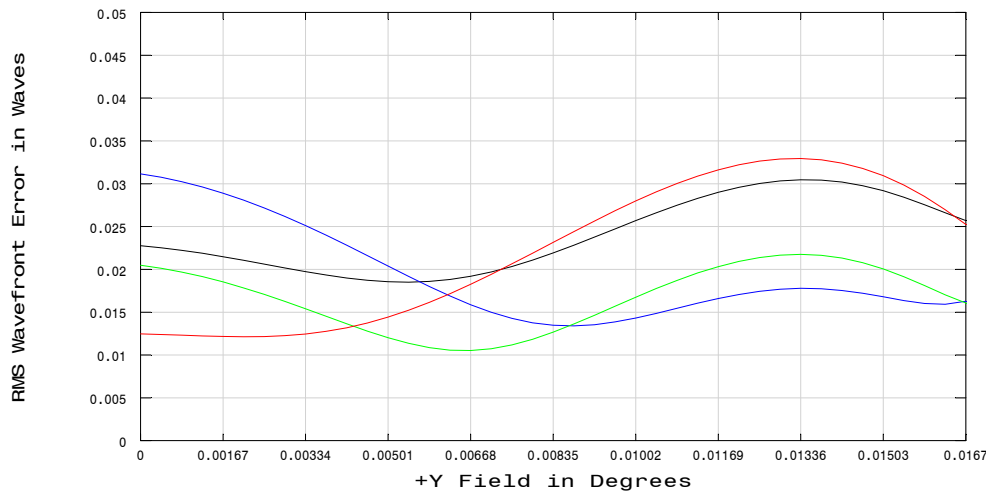




# Opto-Mechanical System



H & Ks Strehls 95 to 97% over field

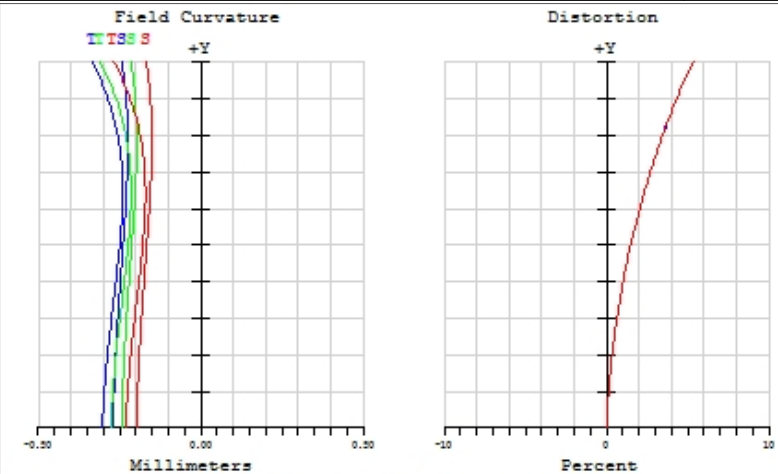


RMS Wavefront Error vs Field

TRICK Optical Design, with telescope and AO  
3/26/2011  
Poly 2 2.15 2.3

TRICK AO v1c trick dichroic cylinder.ZMX  
Configuration 2 of 3

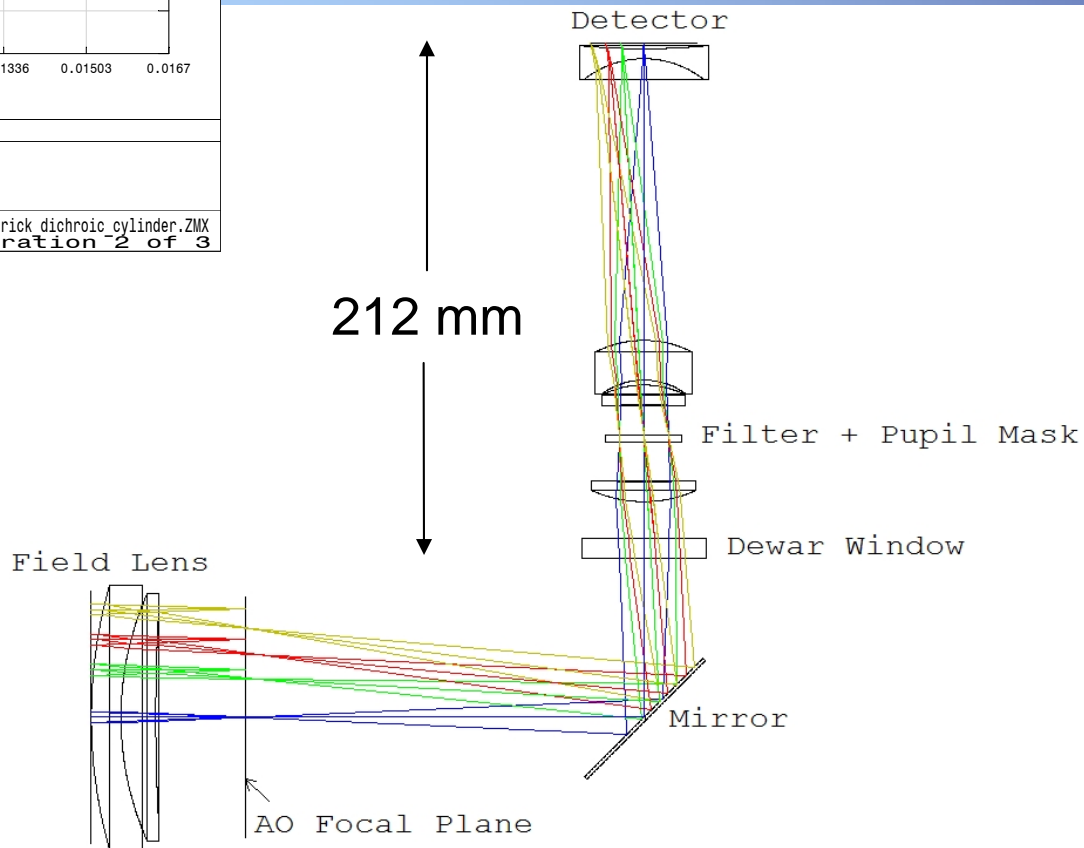
Reference: Centroid



Field Curvature / F-Tan(Theta) Distortion

TRICK Optical Design, with telescope and AO  
3/27/2011  
Maximum Field is 0.017 Degrees.  
Wavelengths: 2.000 2.150 2.300

TRICK AO v1c trick dichroic cylinder.ZMX  
Configuration 2 of 3



# Preliminary Optical Tolerance Analysis

- Monte Carlo analysis for 100 systems, using only focus as a compensation term (other compensators will be identified)
  - Radii to 0.05%, thickness to 25  $\mu\text{m}$ , decenter to 50  $\mu\text{m}$ , tilt to 0.1°
- Result: 90% better than 72% Strehl (50% better than 84%)

<b>Element</b>	<b>Radius (%)</b>	<b>Thickness (mm)</b>	<b>Decenter (mm)</b>	<b>Tilt (deg)</b>
Field Lens 1	0.10	0.050	0.250	0.1
Field Lens 2	0.10	0.150	0.250	0.1
L1	0.05	0.150	0.075	0.1
Filter		0.150		
L2	0.05	0.025	0.075	0.1
L3	0.05	0.050	0.050	0.1
L4	0.10	0.150	0.100	0.1
Field lens spacing		0.100		
L1 – filter		0.200		
L2-L3		0.025		
L3-L4		0.050		



# Reviewer Topics

## 1) Compressor location

- Trade study leading to the current design
- Including the risk of vibration transmissions to the AO system

### Response:

- Compressor location largely driven by safety concerns in the event of the use of a flammable gas (less volume) plus the cost of procuring & installing the lines.
- Anecdotally can't feel vibrations when standing next to compressor (RS estimate  $<10x$  the noise of a computer fan).
- Compressor is suspended from ceiling & sits on a vibration isolated pad.
- Vibrations through the hoses, if any, are damped by appropriately mounting hoses & having bends in the hoses.
- If vibrations become an issue we can move the compressor to the machinery room.





# Camera System Design

Roger Smith  
Caltech



KAON 860 Section 4

# Design Overview - Subsystems

## Operations Software System

- Pre-Observing Tools
- Observation Setup
  - Calibration
  - User Interface
- Observing Tools

## Controls System

- Pickoff & Focus Motion Control
- Camera Device Control
- Supervisory Controller Modifications

## Camera System

- NIR Camera
- Camera Optics
- Camera Controller
  - Filter Changer
  - Cryo-cooler
- Host Computer

## Real-Time Control System

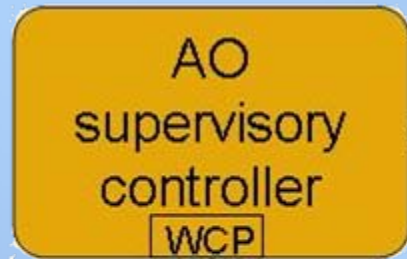
- Camera Data Processing
- TT Determination
- Telemetry Input Mods

## Opto-Mechanical System

- Pickoff Exchange Mechanism
- Focus Mechanism
- Mods to AO bench

# Communication Interfaces

Controls & Operations  
Software  
Systems

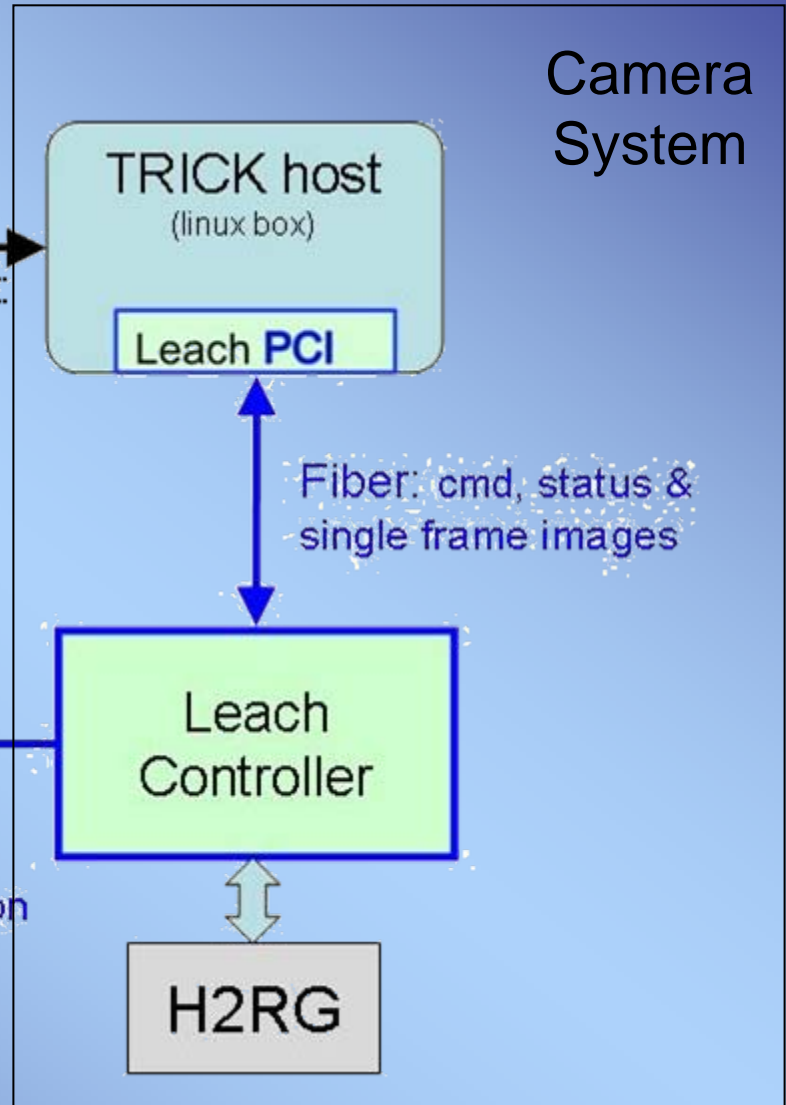


Ethernet:  
cmd & status

Fiber:  
video & configuration  
changes

Video data is self describing  
so RTC knows when config  
changes occur, without tight  
timing through TRICK host.

Camera  
System



Fiber: cmd, status &  
single frame images



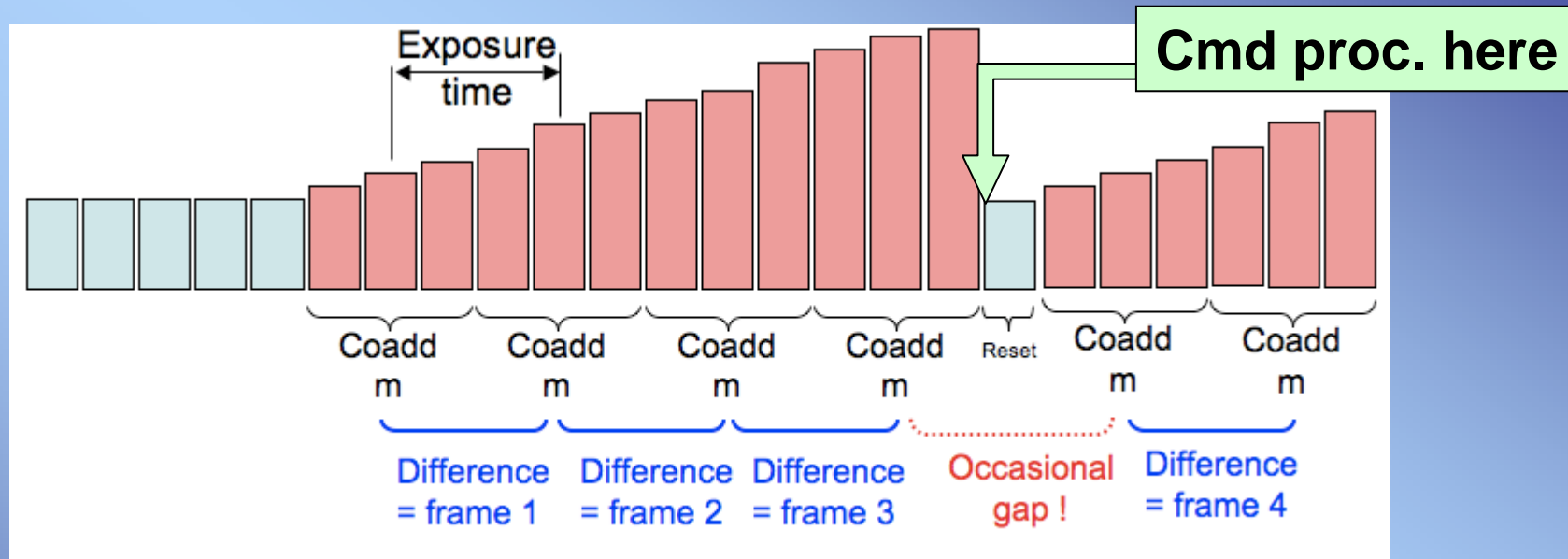
# Data Products

- Via TRICK host (FITS files):
  - Full frame, 4ch CDS readout, for acquisition. 6s min. exposure.
  - Full frame, single channel, mode TBD, for calibration (flats, darks)
  - Film strip: same readout scheme as video data but concatenated in memory and written as single FITS file after finite number of frames limited to several buffer size (Gbytes); multiple ROIs with differing sampling cadences supported as for video link but must be same width so film strip is “rectangular”
- Via fiber link to RTC:
  - Continuous video until commanded to stop. Raw pixels from multiple regions of interest, interspersed with “configuration packets” describing readout parameters.



# Camera System - Readout

“Differential Multi-Accumulate with Sparse Reset”



e.g.. If resetting once per second and reading one 4x4 pixel ROI (140 $\mu$ s), then bright limit > 100,000e-/s/pixel and there are 7000 ROI reads per reset. Coadding 7 reads, then differencing produces 1000 exposures per second and about  $\sqrt{7}$  noise improvement: read noise < 5 e-. The RTC must interpolate over 1.14 ms gap lost to reset. Duty cycle is 99.9%.



# Readout Scheme

- Support for up to eight ROIs, with different visitation frequencies

- ROI table

- Programmable
- Updates on the fly, at reset.

- Pseudo-code:

```

while video=on {
  check for command
  select full frame
  set detector's global reset
  send config packet to video link
  clear global reset
  for i=1 to CYCLES_PER_RESET {
    for n = 1 to NUM_ROI {
      if (i modulo Pn = 0 {
        send coordinates (Xn,Yn,DYn,DYn) to H2RG
        read/transmit ROIn
        delay for Tn
      }
    }
  }
}
    
```

PERIODICITY	DELAY	START COL	START ROW	# COLS	# ROWS
1	0	1098	898	4	4
1	0	198	297	4	6
3	...	...	...	...	...
P4	T4	X4	Y4	DX4	DY4
0					

Every iteration

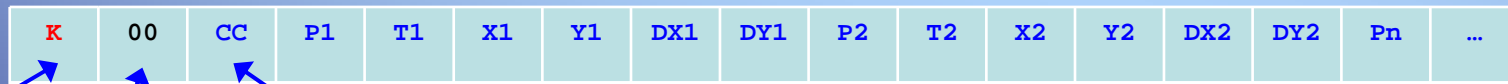
Every 3<sup>rd</sup> iteration

**NB: more pixels per frame means fewer coadds & higher read noise, or lower frame rate**



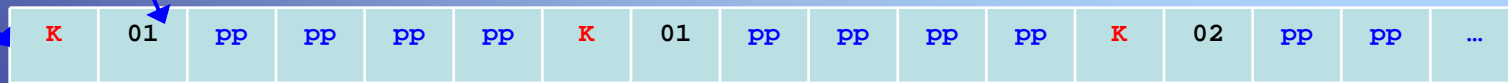
# Configuration Packet

- Video data is self-describing; all values are 16 bit.
- Packet Header = 16 bit word identifying the data to follow as:
  - ROI table (\$00) [see example below]
  - data for ROI 1-8 (\$01-\$08)
  - RESET (\$52)
- Readout configuration only changes at reset.
  - 16 bit configuration counter increments on change [CC]
- Config Packet identified by Special Character (K.29.7) Control Code
  - supported by fiber optic interface
- Config Packet is sent at every reset. example:



ctrl code      header      config counter (followed by ROI table)

- data packet example (for two 2x2 ROIs, P1=1 and P2=2):

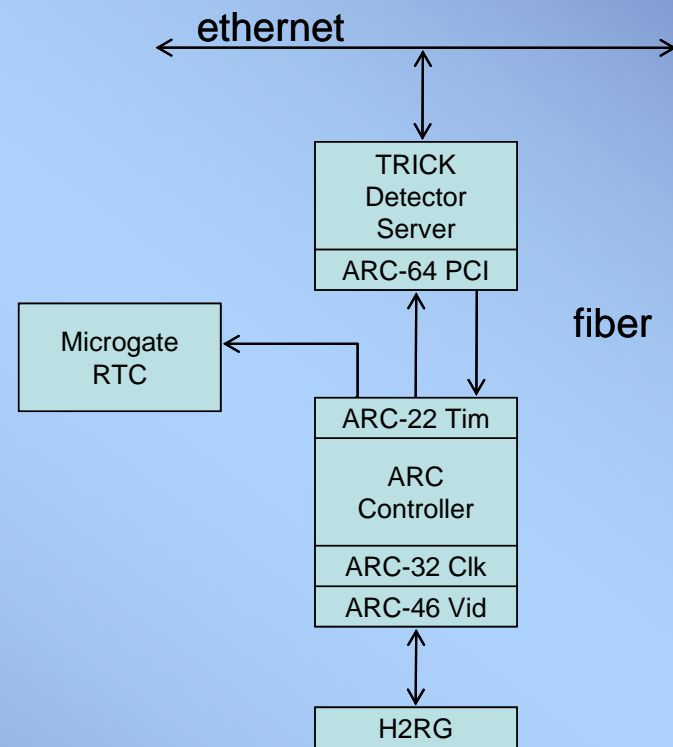
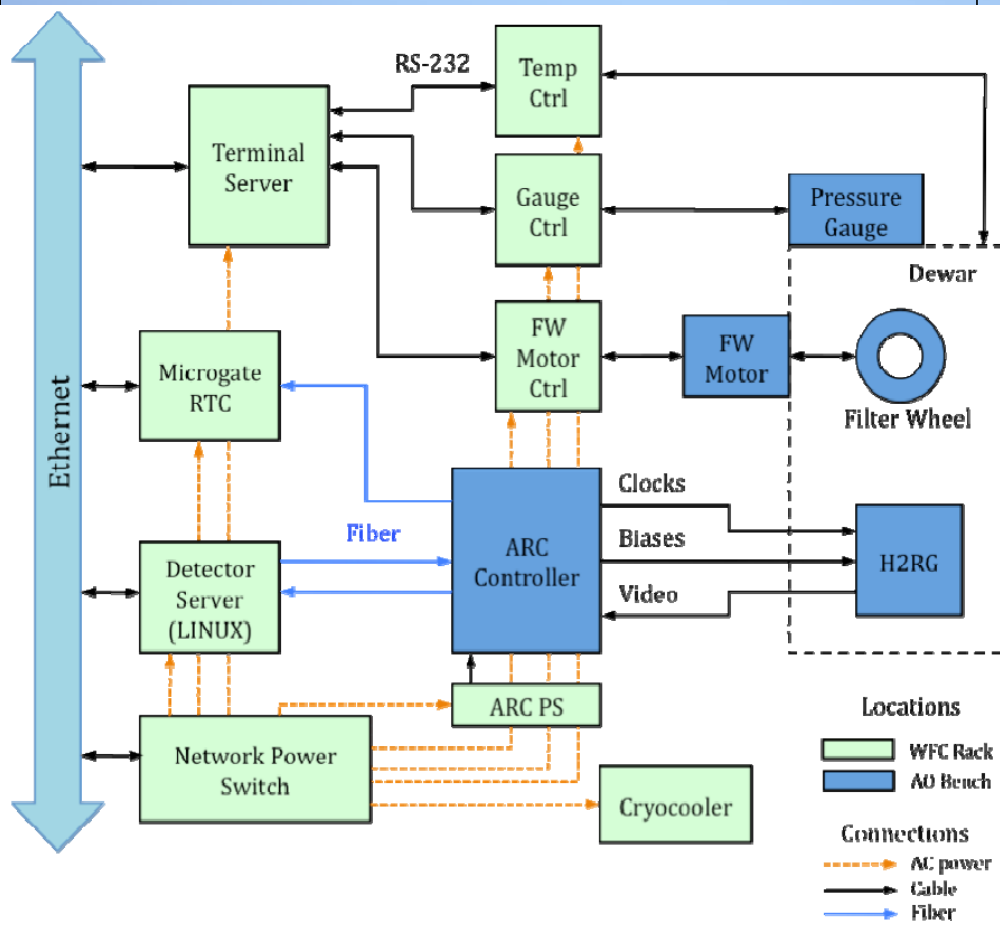
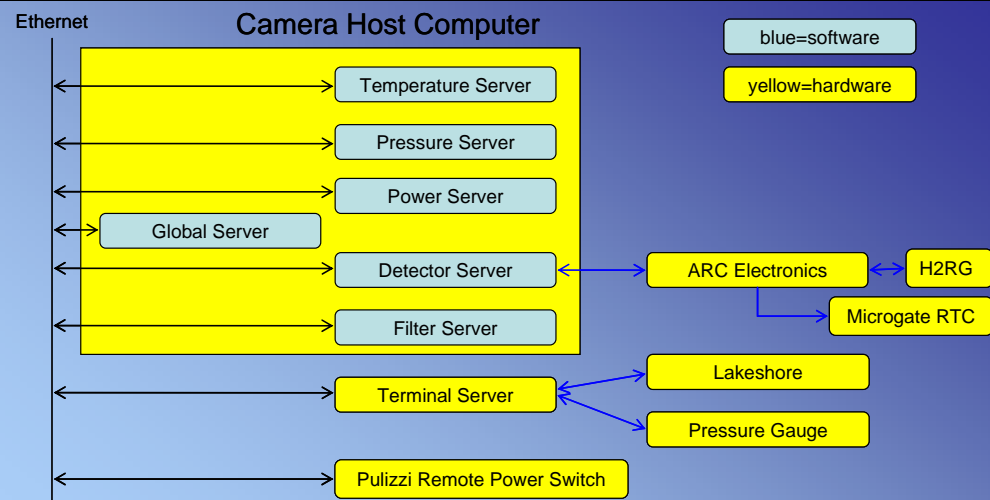


pixel values

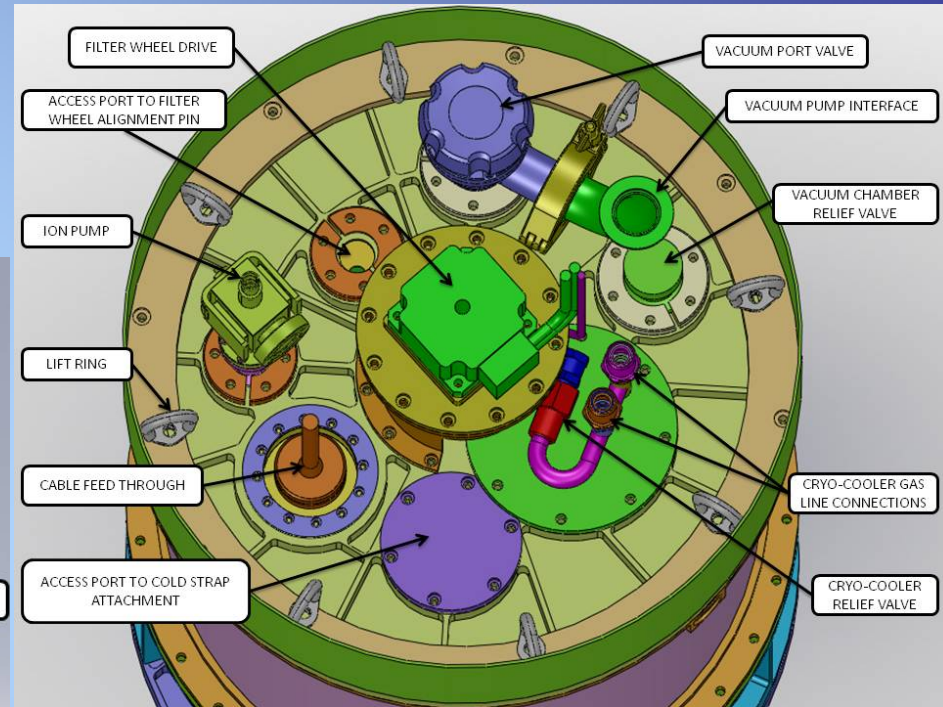
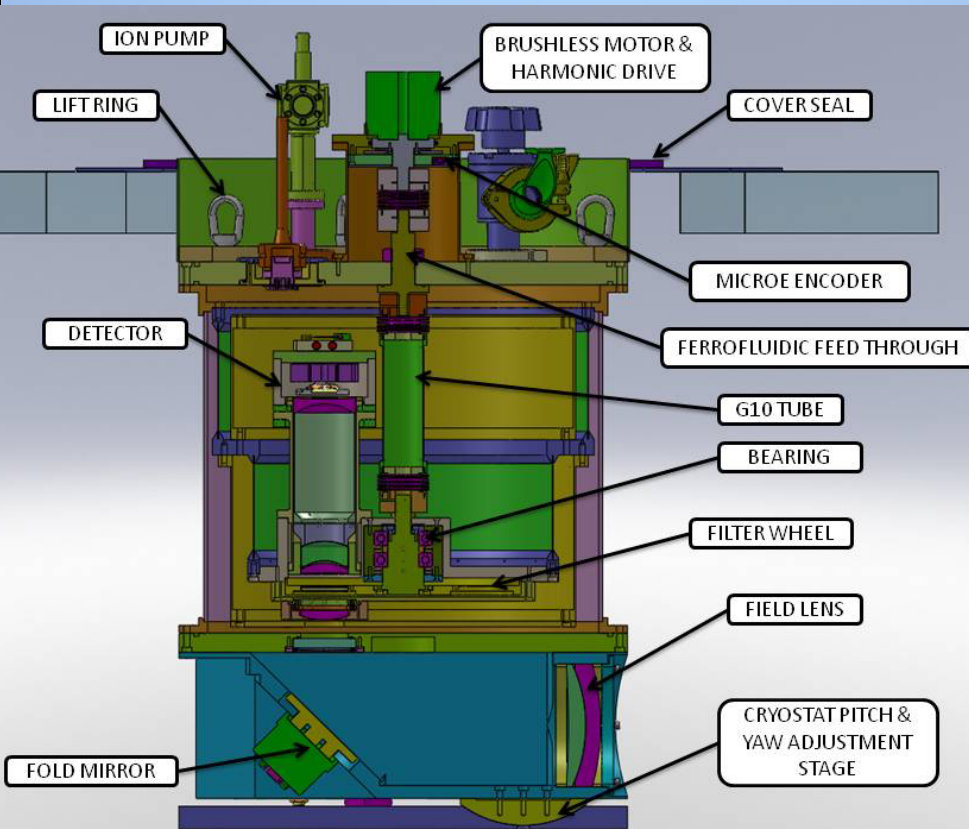




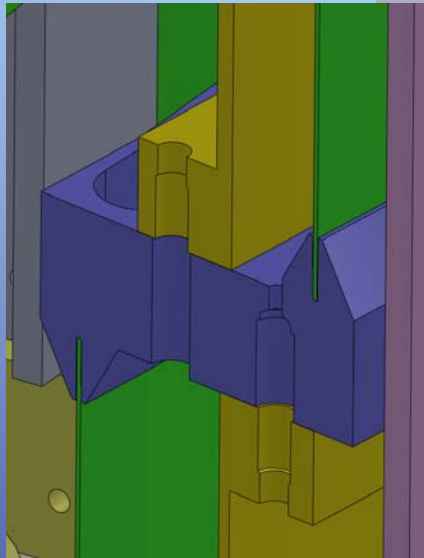
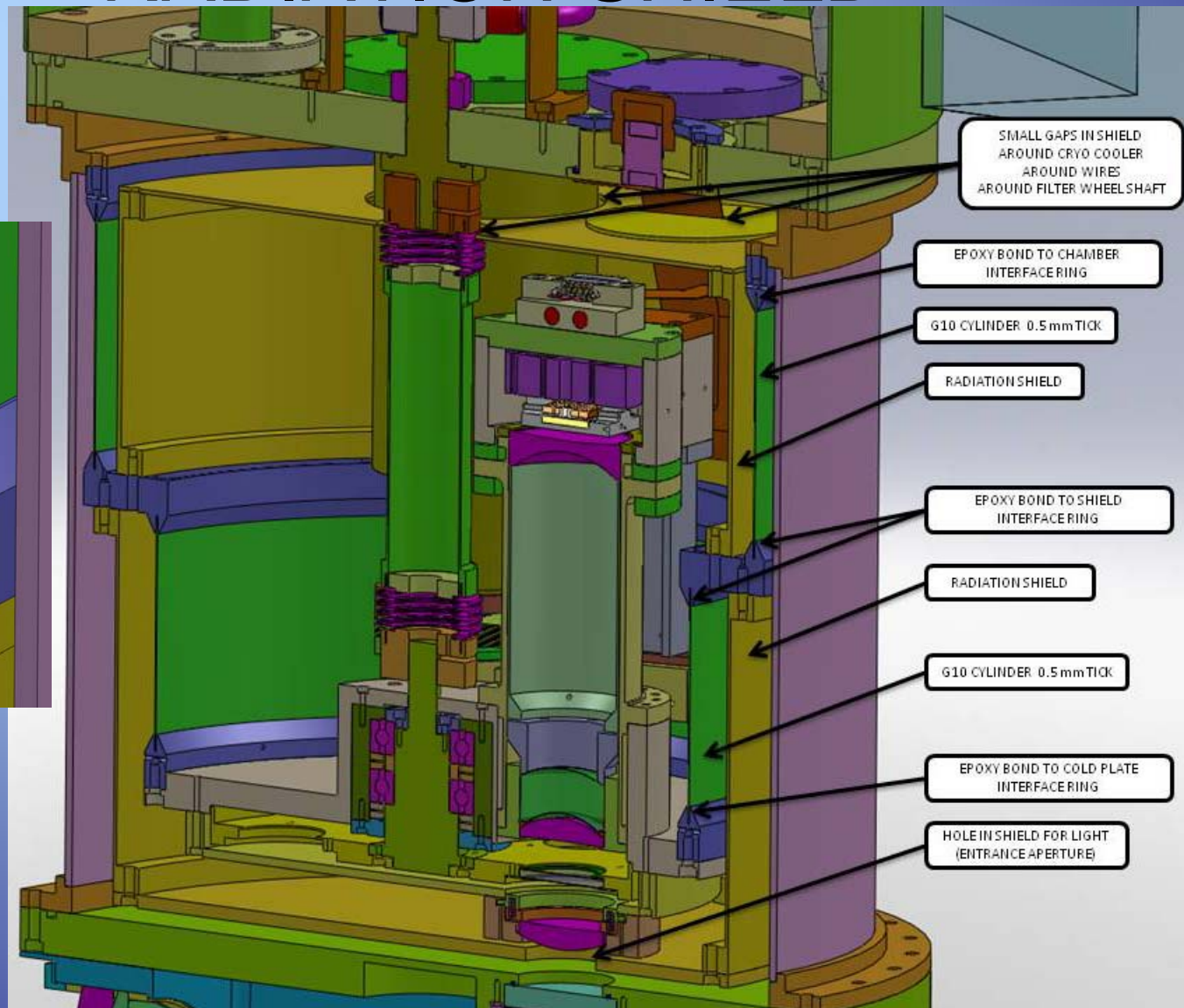
# Camera Hardware & Servers



# Camera Dewar



# INTERNAL SUPPORTS AND RADIATION SHIELD



# MASS BREAKDOWN

RIQ-CBO3: Is there a plan to do a flexure analysis of the TRICK system during DD and also to check the impacts on AO bench?

Much heavier than originally estimated:

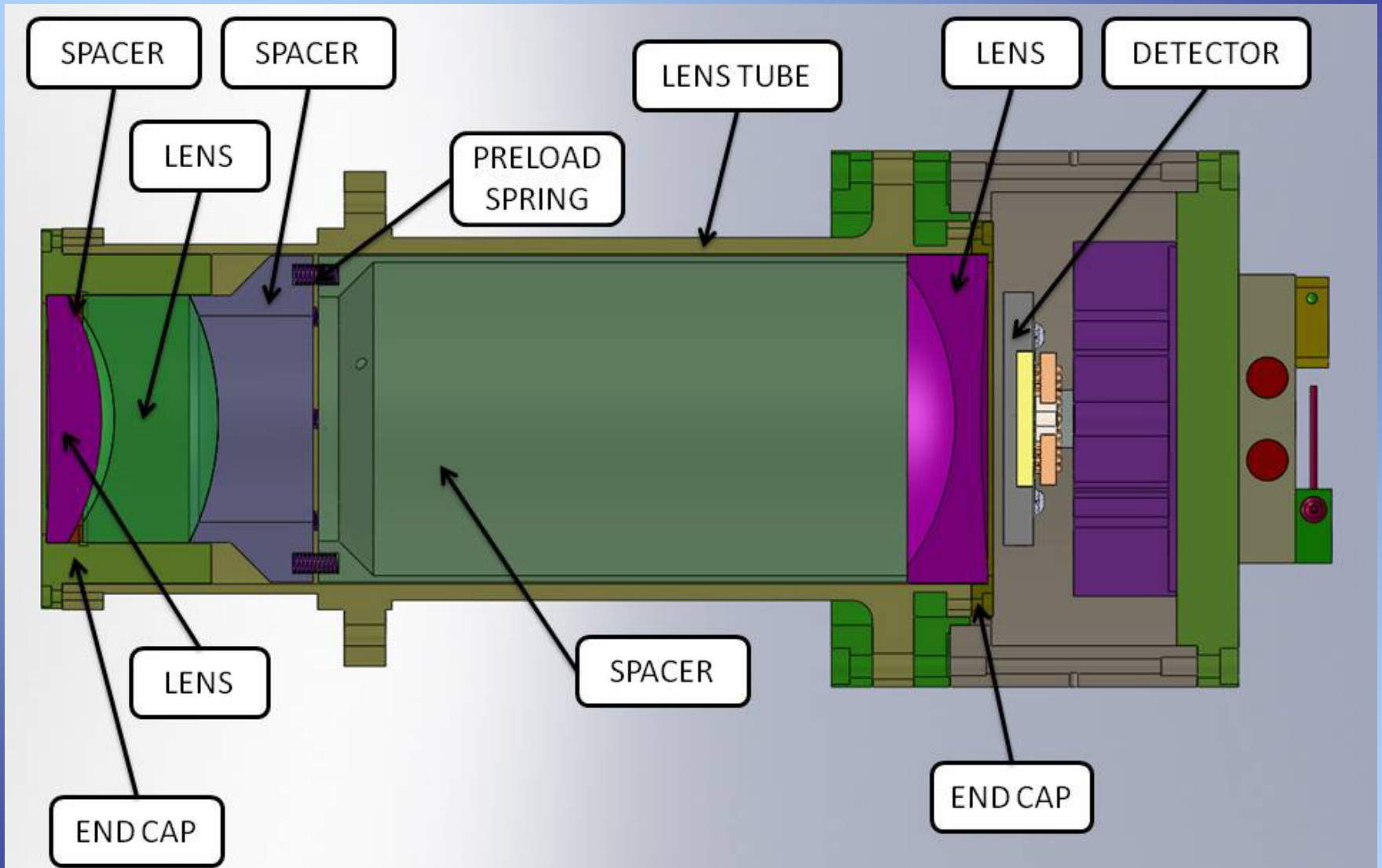
- Cryostat and base, no light weighting = 103 lb
- With light weighting = 85 lb
- Analysis in DD phase is planned to determine if cost of light weighting is justified, etc.



	current	light-weighted	~ cost
Top cover	9.72 lb	5.26 lb	\$1.5K
Bottom cover	9.37 lb	3.5 lb	\$ 2K
Cold plate	3.5 lb	2.8 lb	\$500
Base	24.5 lb	17.5 lb	\$1.5K



# LENS MOUNTING



# Filter Pupil Mounting

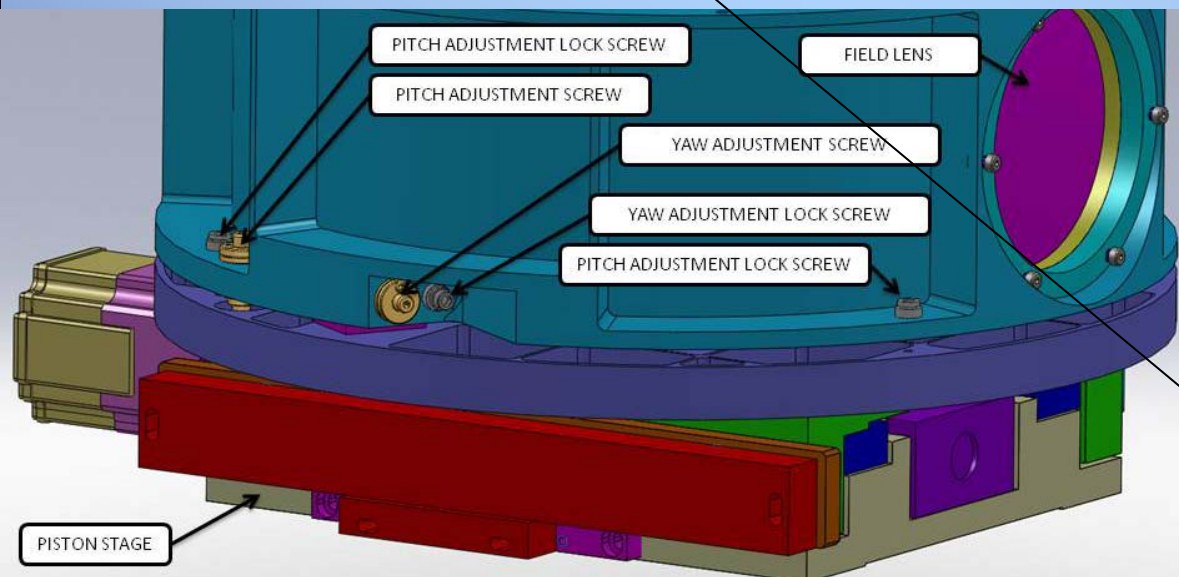
RIQ-RDC6: It's not clear to me how the filters/pupil stops will be mounted? What material will be used. Is there any mechanical design work done yet for the filter holders/pupil masks. I'm concerned about restraining the filters without possible coating damage to the filters.



- Contact made outside optical path.
- Precise pupil stop machined into filter wheel itself, for best repeatability and minimal radial position variation from filter to filter.
- Tangential position errors will be corrected with drive system.

# DEWAR ALIGNMENT MECHANISM

- Stage between bench and entire assembly provides focus.
- Pitch and Yaw adjustment align cold pupil stop with pupil image.
  - Aligns reimager axis with AO optical axis.
  - Spherical bushing places center of rotation at center of image plane produced by AO system (behind field lens).





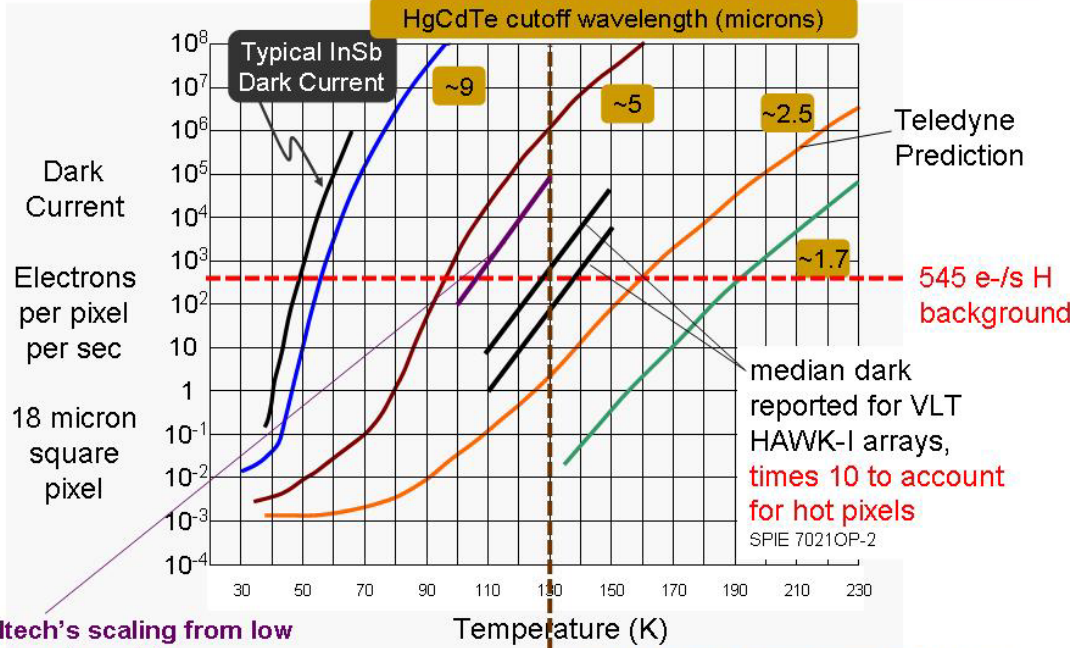
# THERMAL LOAD & COOLING TIME

RIQ-BCO3: Have you performed a cool-down analysis and estimated the time for cool-down and warm-up?

- Equilibrium thermal load on cryocooler < 4 W
  - 0.45 m<sup>2</sup> radiation shield : < 2 W
  - 0.0009 m<sup>2</sup> gaps have unit emissivity: 0.02 W
  - Radiation through entrance window: 0.4 W
  - Conduction through G10 Shield support: <0.25 W
  - Conduction through G10 drive shaft: 0.05 W (allocation)
  - Conduction through electrical wires: 0.15 W (allocation)
  - Heater power allowance: 1 W
- Cryotiger with high performance head and PT14 gas: 15 W peak
- Cooling time currently ~36 hr, will be reduced to < 24hr
  - by light-weighting cooled mass from 6.5kg to ~4kg.
  - In DD phase will adapt existing numerical models to provide better estimate: may permit cost saving on low emissivity coatings.
- Warming time = 4 hr: active heating enforces 1K/min slew rate.
  - ~80 W heater power from 2nd servo loop on Lakeshore controller

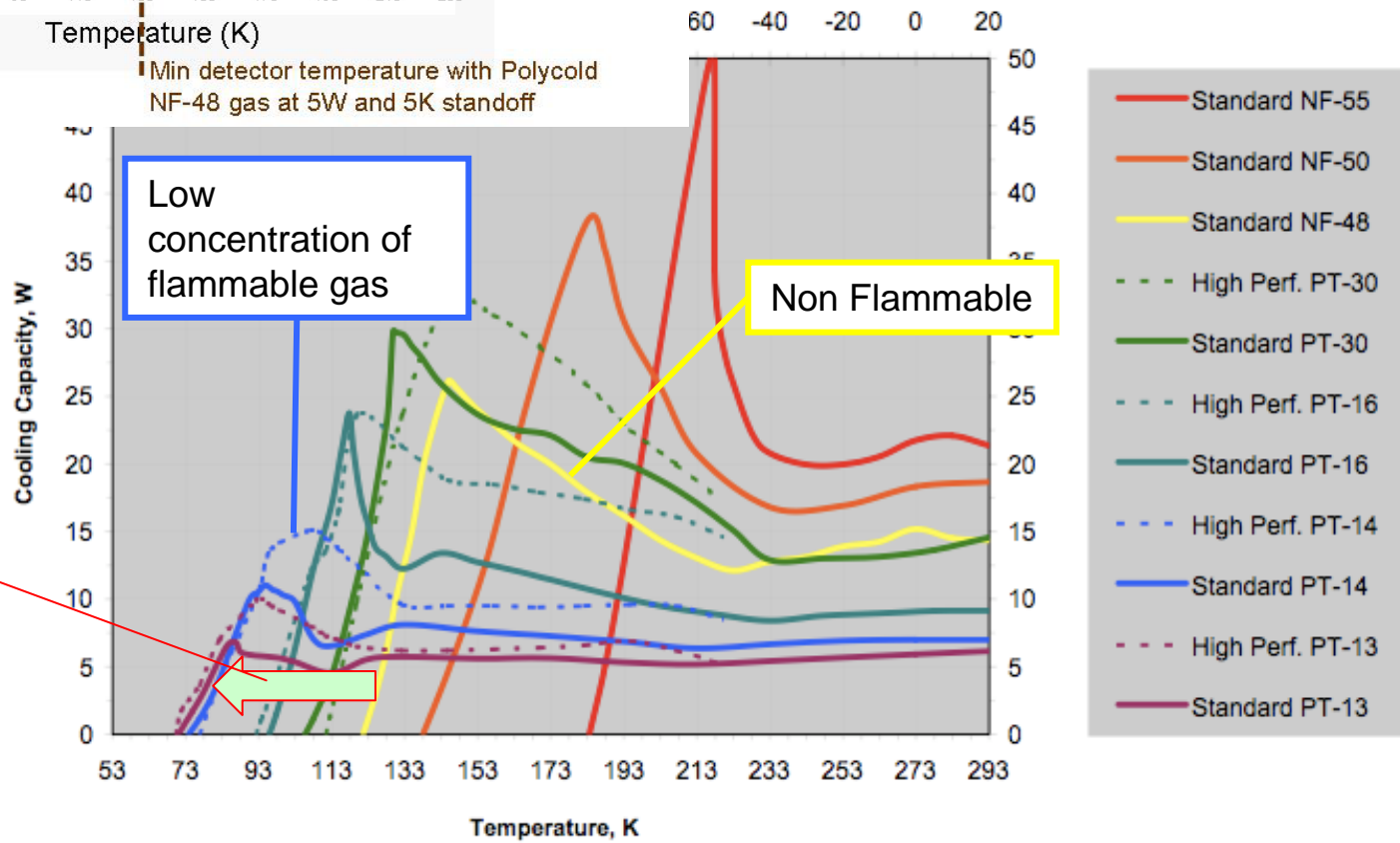


# Camera Cryocooler



Caltech's scaling from low temperature data (hot pixels = 10x median)

## Capacities at 60Hz



Lower temperature suppresses hot pixels that appear at the high detector bias desired to reduce noise



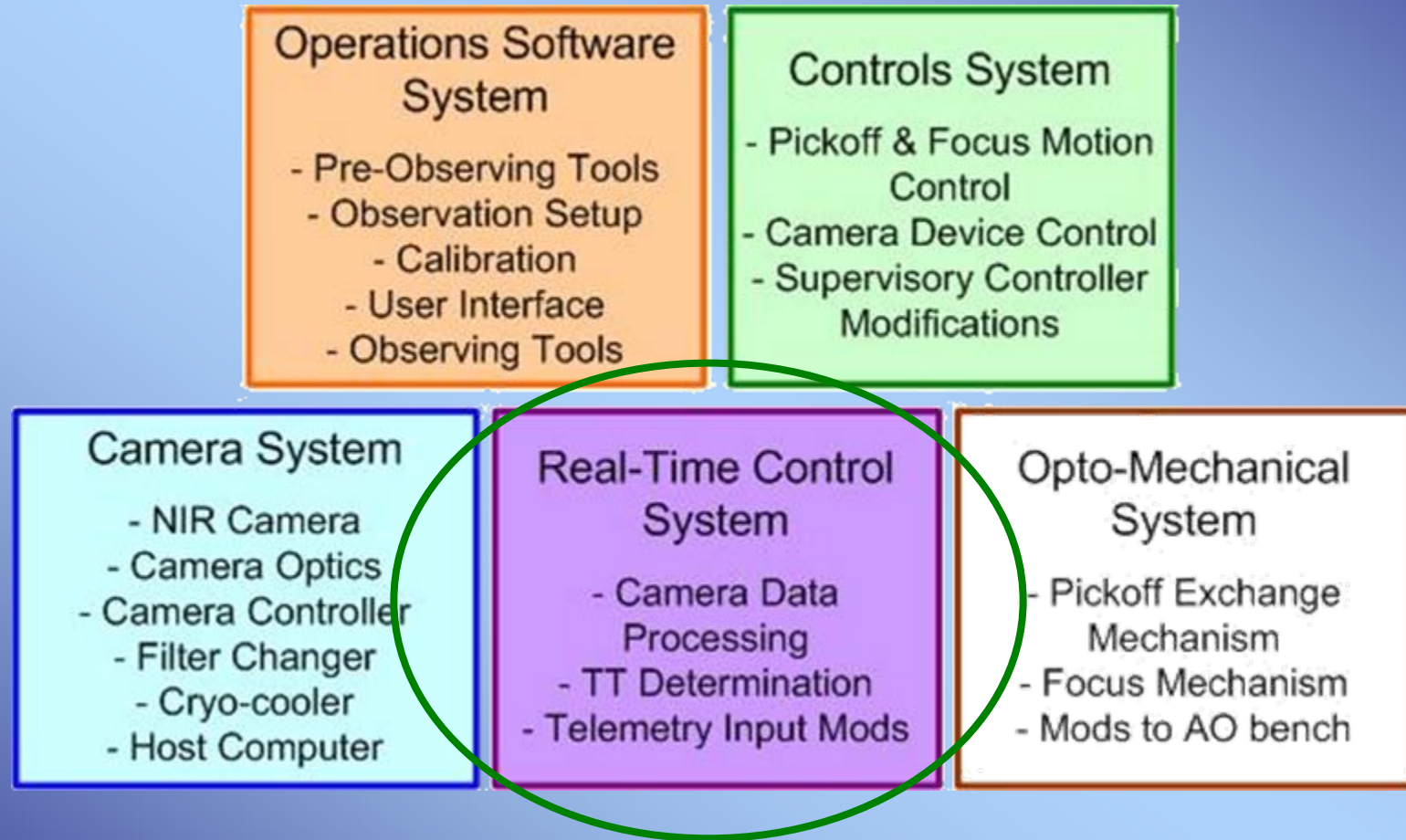
# Real-Time Control System Design

Roberto Biasi  
Microgate



KAON 824 + KAON 860 Section 5 + KAON 862

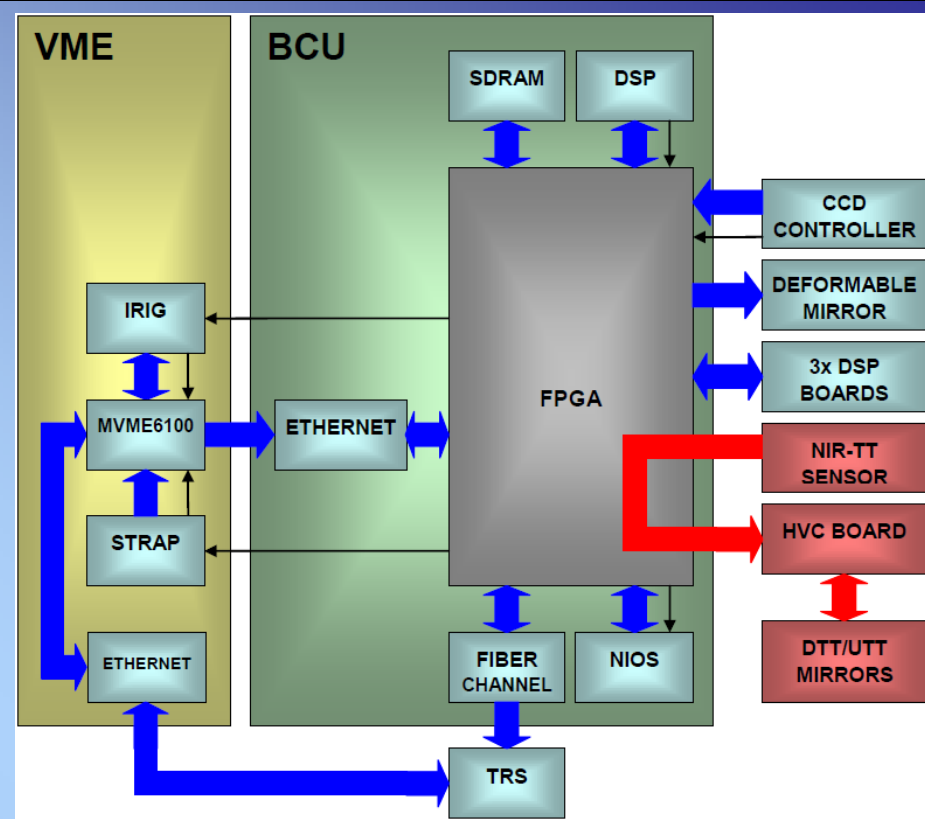
# Design Overview - Subsystems



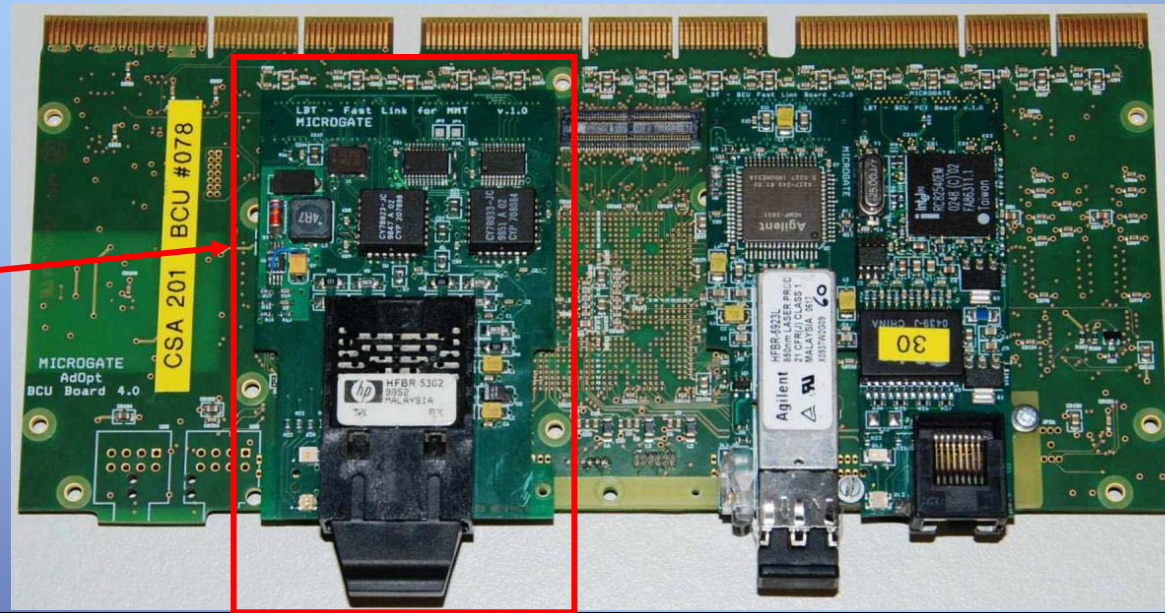


# RTC Design

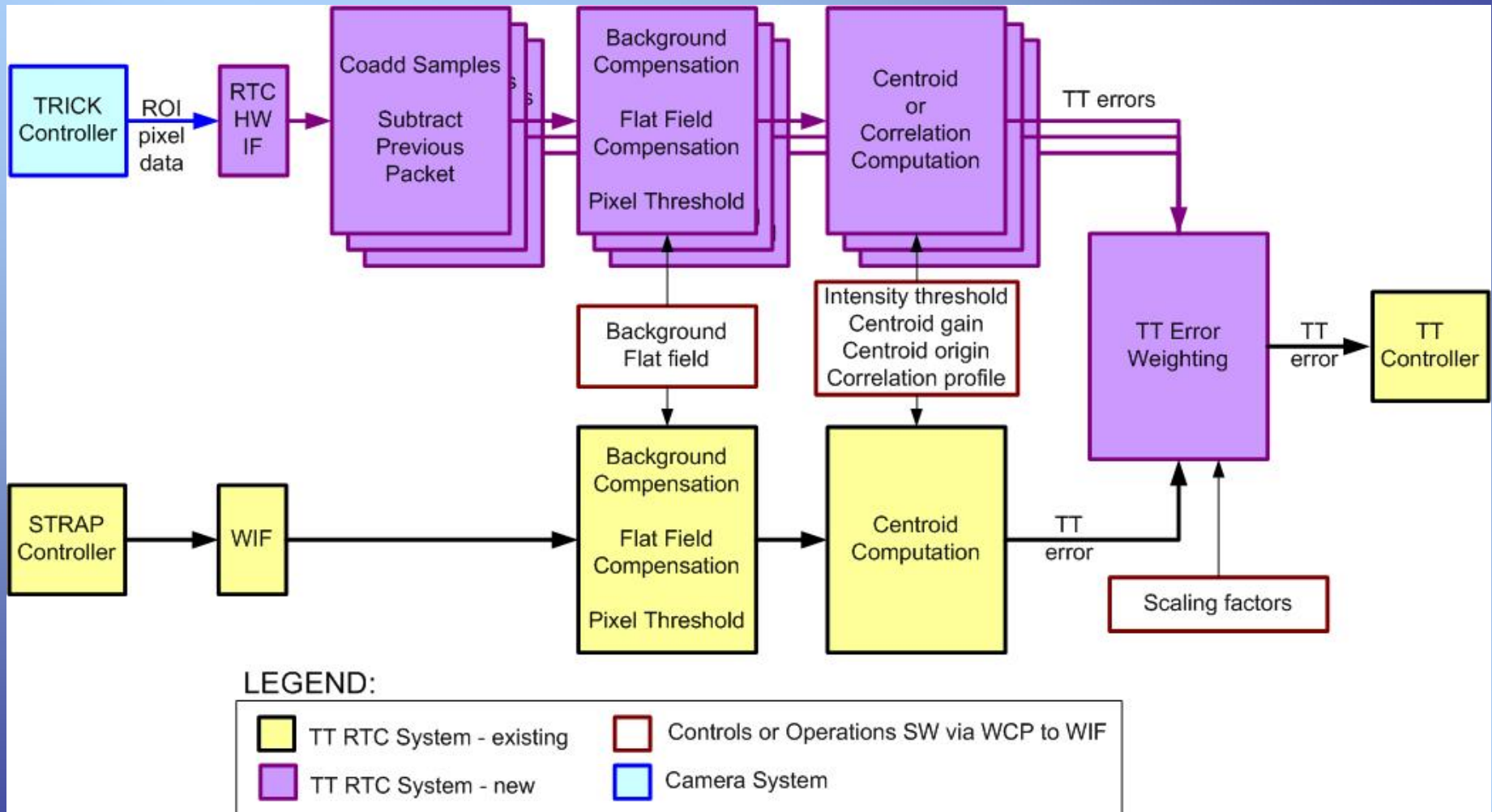
- Requirements documented in statement of work (KAON 824)
- PD documented in KAON 862
  - Update to NGWFC RTC as-built document



NIR TTS to BCU interface board



# RTC – Control Loop





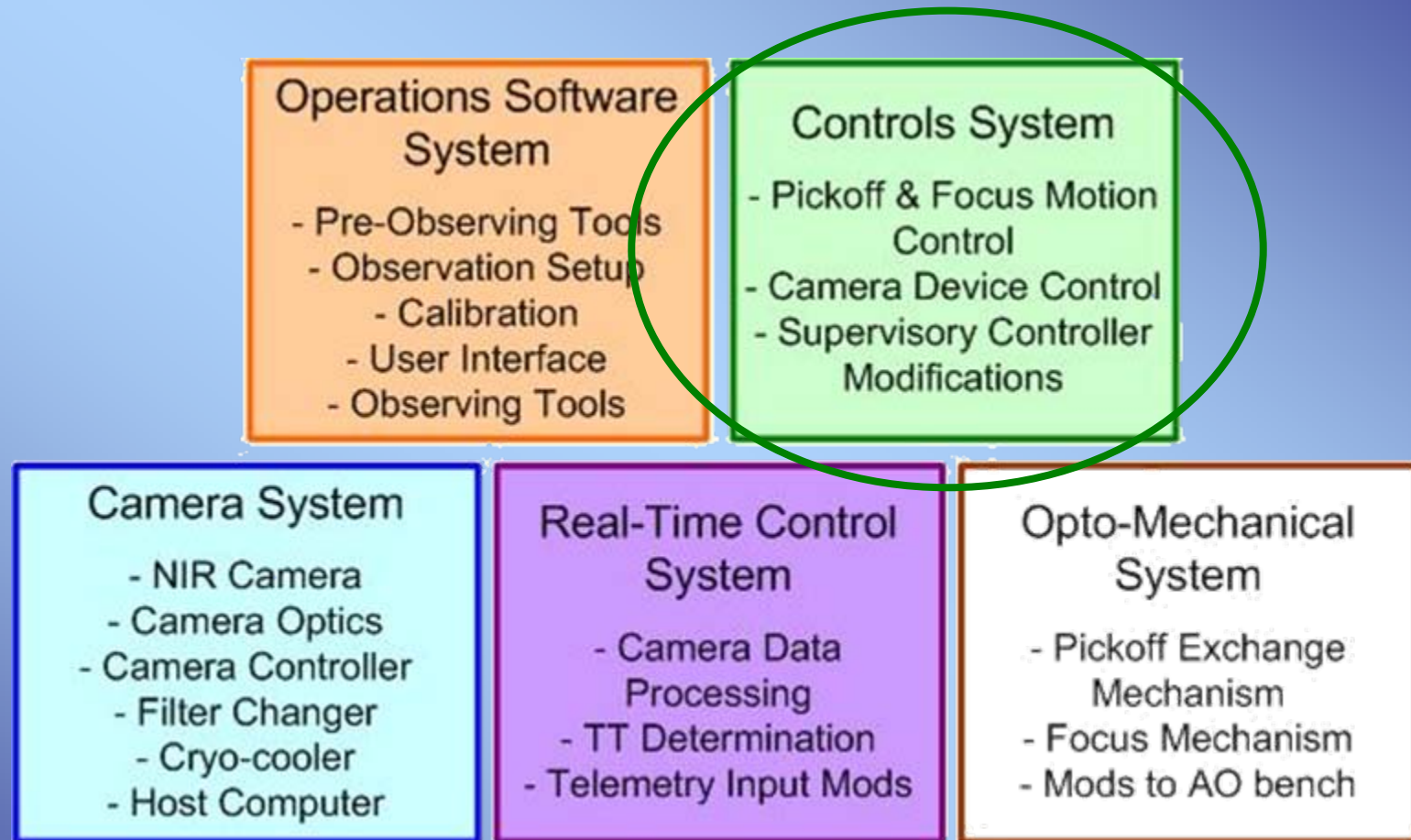
# Controls System Design

Peter Wizinowich  
WMKO

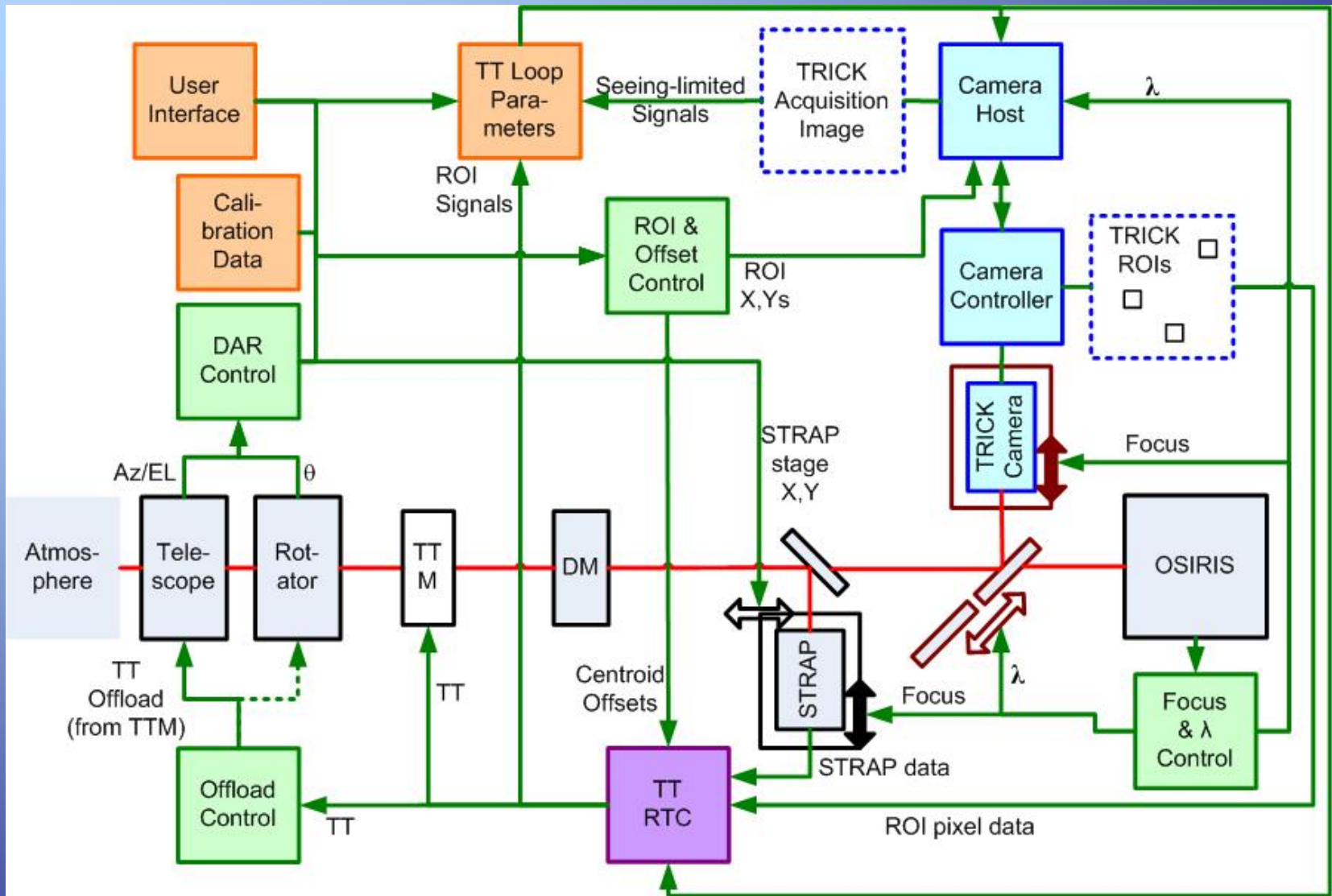


KAON 860 Sections 6 & 7

# Design Overview - Subsystems



# Controls



## LEGEND:

Light path	Existing AO HW	Camera System	Controls System
Data path	Opto-Mech. System	TT RTC System	Operations Software



# Motion Control

- Two 1 degree of freedom linear position control devices:
  - Stage for optical pickoff & stage to match TTS focus to OSIRIS focus
  - Control provided by existing AO PMAC motion control hardware
  - Software interface & control provided via observatory standard command & feedback functionality, plus sequencer & state machine control
  - Engineering GUIs will be implemented to interface with devices
- Focus compensation:
  - Focus position of the NGS-WFS & LBWFS/STRAP are automatically adjusted when science instrument or configuration changed
  - Same correction will be applied to the NIR TTS focus stage
  - Field curvature for NIR TTS & OSIRIS will be measured & included in focus compensation



# ROI Location & Centroid Offset Calculation

Fixed offsets

Image shift from pickoff  
Image shift from OSIRIS plate scale  
Image shift from distortion  
Image shift from field curvature

Dynamic offsets

Non-sidereal

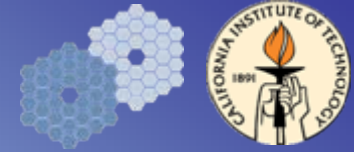
Convert to AO  
Xim/Yim coordinate

TRICK DAR offset  
AUTRESX, AUTRESY  
positions from TCS for  
user requested offsets  
including dither and nod

- Convert to pixels
- check against bad pixel map
- send out ROI location to NIR TTS host computer
- send centroid offset to RTC

- Initial ROI locations & centroid offsets determined during acquisition
- ROI values sent to Camera controller
- Centroid offsets sent to RTC





# Observing Operations Concept Document (OOCD) & Operations Software

Chris Neyman  
WMKO

KAON 859  
KAON 860 Section 8

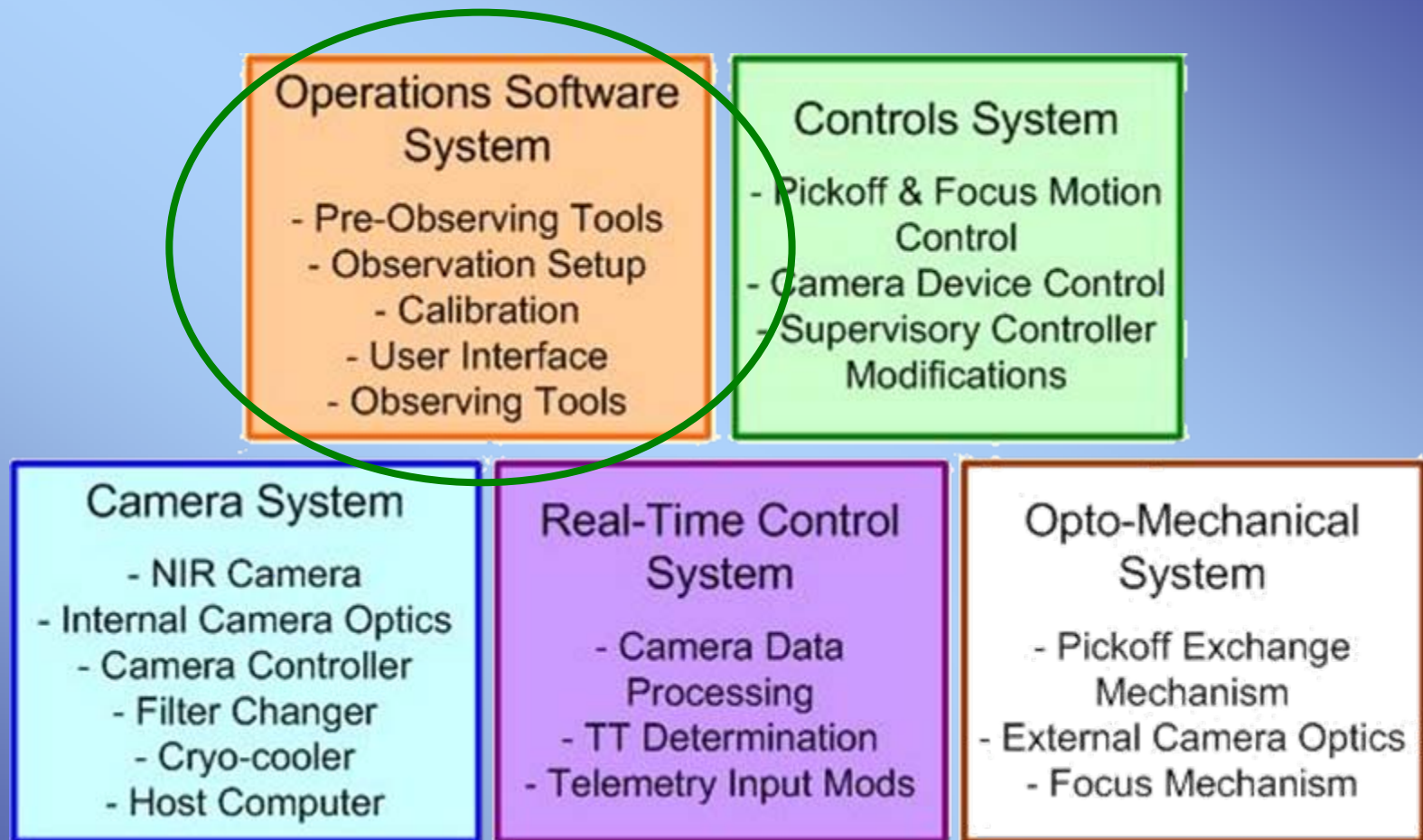


# Observing Operations Concept Document

- Narrative explaining how system is used by 3 key groups
  - Astronomers, Support Astronomers, & Observing Assistants
  - Planning, Setup, Calibrations & Observing considered
  - Reviewed by Science & AO operations teams
- Guided design of user software
- A number of descopes in updated SEMP could impact O OCD
  - AO prediction & performance tool
  - AO/OSIRIS “micro move” tool (< 20 mas)
  - Multiple TT guide star features: tomography & optimization
  - NIR TSS not directly interfaced to MAGIQ
    - Studied in PD (discussed in later “reviewer topics” slide)



# Design Overview - Subsystems



# Operations Software

- Pre-Observing
  - Acquisition planning
  - Performance estimation
- Observation Setup
- Calibrations
  - Camera, focus & distortion
- User Interfaces
- Observing Tools
  - Acquisition
  - TT performance monitoring
  - TT parameter optimization
  - Nodding, dithering & repositioning
  - Seeing disk & sky background subtraction





# Reviewer Topics

## 4) Software

- Why not use existing tools such as MAGIQ for adjusting the guide star selection during observations and for centering the science object?

Response:

- Sorry for confusion on this topic
  - due to incomplete updates of the O OCD & PDM
- MAGIQ/ACAM will primarily be used for acquisition
- NIR TTS camera only used as a backup if IR field ID required
- Neyman, Lyke, Kwok & LaVen concluded this was a workable solution considering:
  - Still need a visible star for LBWFS
  - Use visible star to adjust telescope pointing with ACAM/MAGIQ
  - Catalog position good enough to assign initial ROIs (16x16, 8x8)
  - Determine if the NIR star is usable (not a double, galaxy, etc.) by closing tip-tilt loop & monitoring performance with the NIR Status tool
  - NIR TTS full frame image display provides IR field ID if required

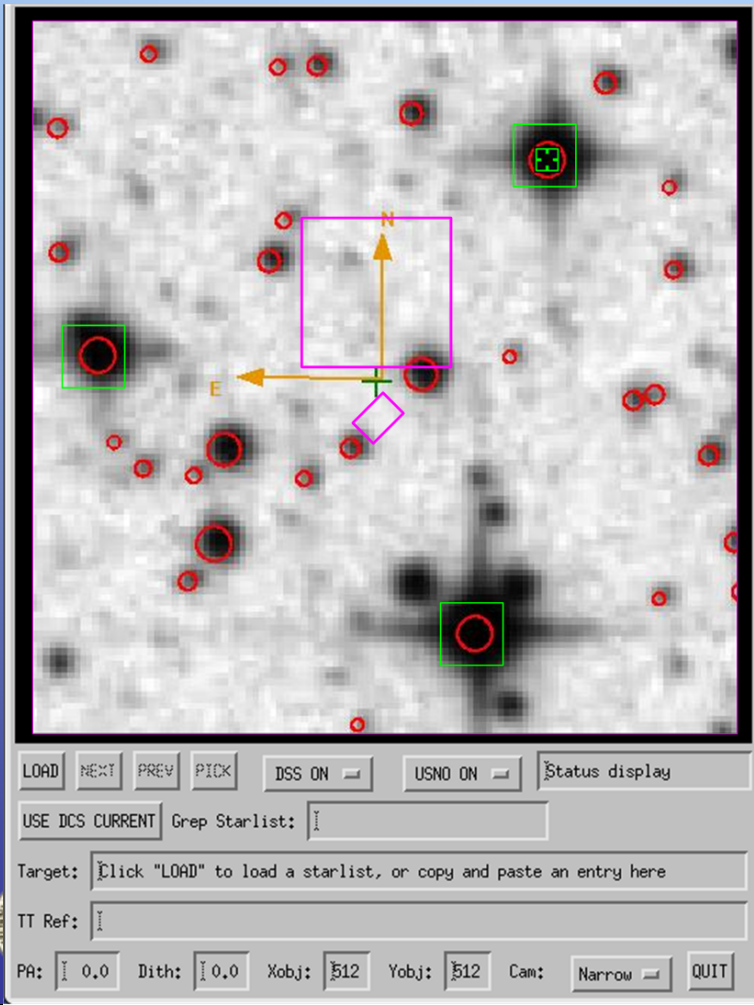




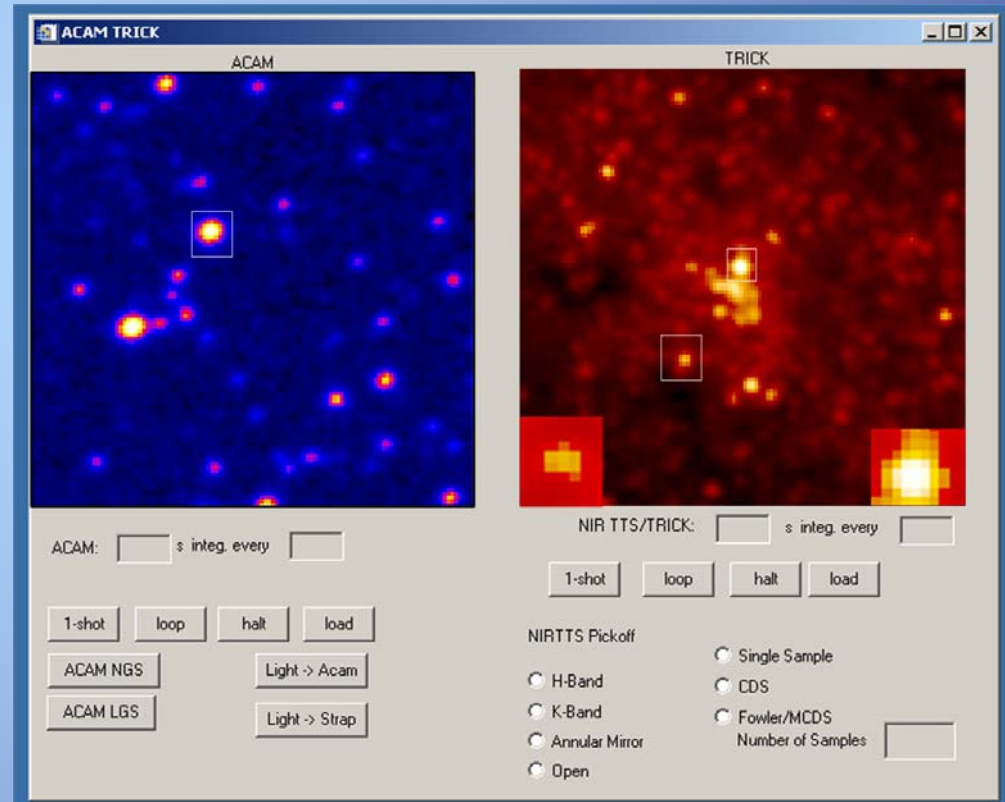
# Operations Software Tools

## TTS/NIR planning widget

Features not in web guide star selection tool (reads keywords, matches detector orientation)



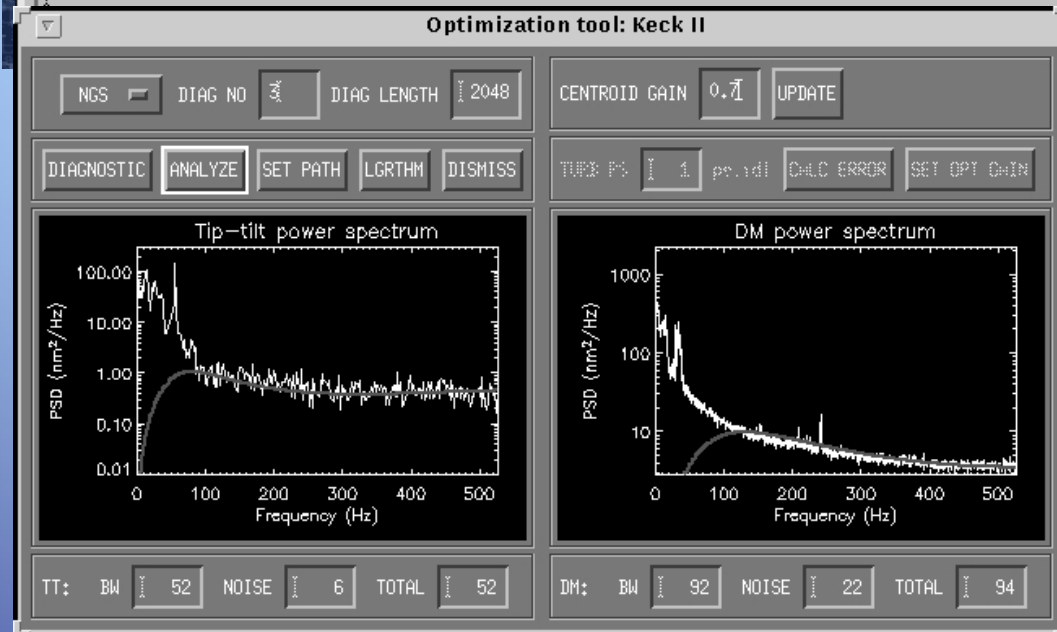
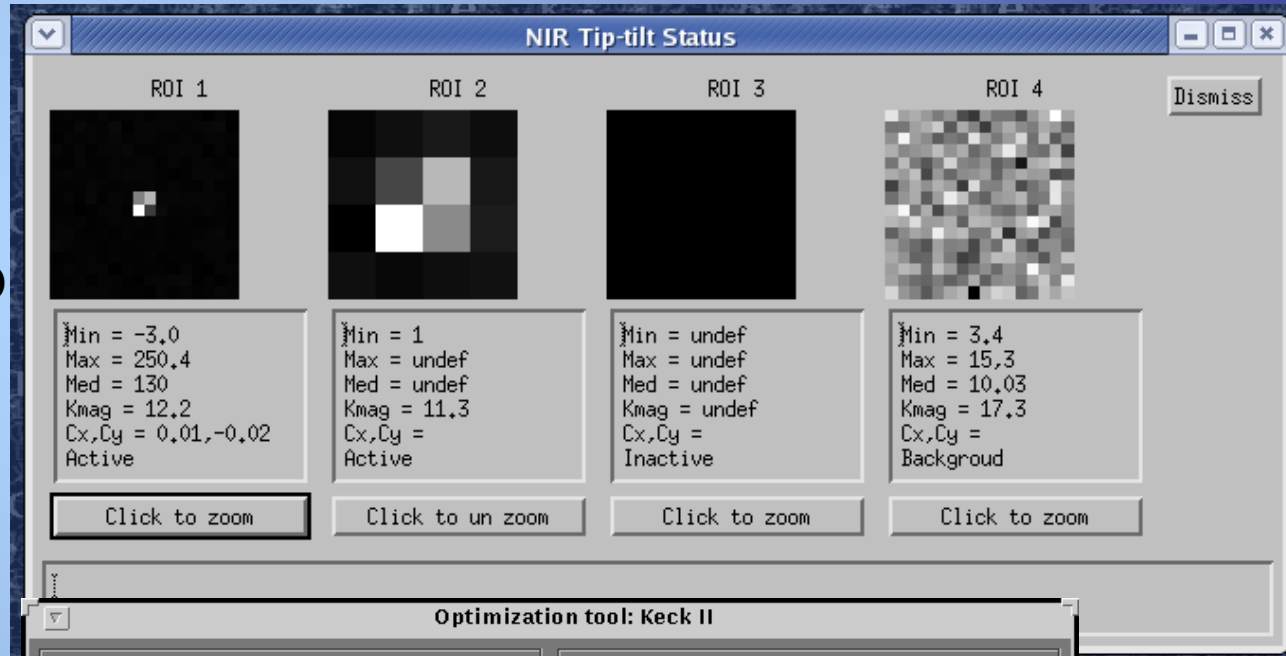
## ACAM & TRICK (full frame) Course acquisition & field ID





# Operations Software Tools

NIR TTS status GUI  
Monitor when initializing  
AO correction & when AO  
loops closed



AO optimization  
Update for NIRTSS



# Reviewer Topics

## 3) Centroid algorithm

- How do you plan to estimate the centroid gains?

Response:

- 3 methods are still under consideration (for single star centroiding):
  - 1) Know transfer function (loop gain is known!) & high frequency PSD ~ white, allows estimate of centroid gain (WMKO)
  - 2) Dithering tip-tilt before science exposure (ALTAIR)
  - 3) Use direct estimation of image “size” from seeing disk and Strehl estimates (PDM sections 8.5.4 & 8.5.5)



# AO Optimization Discussion

- Ideally would do more performance analysis & testing of optimization approaches
  - May be able to continue to get some support from GMT & van Dam
- Current plan, due to tight contingency, is to focus our limited resources on the following priorities (lower priorities will drop off the list to ensure the optimization task stays within budget):
  - Optimization tools in place for centroid algorithm operating near null (within ~10 mas to accommodate DAR)
  - Development of a simplified algorithm for determining when to switch between the NIR TTS & STRAP
  - Optimization tools for centroid algorithm operating off-null
  - Optimization tools for correlation algorithm
  - Development of a more optimized algorithm for switching between the NIR TTS & STRAP



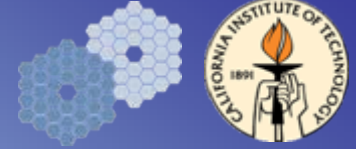
# Operations Software Tools: AO prediction tool

- This tool was descoped in SEMP (from 260h to 8h)
  - Commission system without tool
  - Produce performance tables from commissioning data

The screenshot displays the IDL AO prediction tool interface, which is divided into several functional areas:

- GUIDE STAR CONFIGURATION:** A table with columns for Name, Distance, NIR TTS, STRAP, and LBWFS. It contains four rows, with the first row highlighted.
- STARLIST:** A table with columns for Name, RA, DEC, Equinox, and Options. It also contains four rows, with the first row highlighted.
- Configuration Controls:**
  - Buttons: "Use Current NGS for NIR TTS", "Use Current NGS for STRAP", "Use Current NGS for LBWFS", "Save NGS Configuration to Starlist".
  - Radio buttons: "5x5 LBWFS", "20x20 L:BWFS".
- Source Atmospheric Param:**
  - Radio buttons: "User Selected", "MK MASS/DIMM".
  - Input fields: "r0 (cm)" set to 10, "theta0 (arc seconds)" set to 20.
- Tracking Parameters:**
  - Input fields: "theta\_tilt (arc seconds)" set to 45, "f\_G(greenwood) (Hz)" set to 28, "f\_TG(tracking) (Hz)" set to 6.
- Current Cn2 and Wind Profiles:** Two plots showing atmospheric profiles. The left plot is titled "Current Cn2 and Wind Profiles" and the right plot is titled "CFHT WX Tower MASS Profile".
- Prediction Mode:** Radio buttons for "User Selected" and "Use current NGS setup".
- NIRTTs Pickoff:** Radio buttons for "H-Band", "K-Band", "Annular Mirror", and "Open".
- Science Wavelength:** Radio buttons for "K-Band", "H-Band", and "J-Band".
- Performance Parameters:** Input fields for "Strehl", "FWHM (mas)", and "50% EE".
- Buttons:** "Save AO Performance" and "Calculate AO Performance".
- Ensqared Energy:** A plot showing the relationship between Strehl Ratio (SEE) and theta (mas).
- PSF:** A plot showing the Point Spread Function (PSF) as a central bright spot with surrounding diffraction orders.





# Acceptance, Integration & Test

Peter Wizinowich  
WMKO

# Acceptance

Each system tested against their requirements & interfaces prior to acceptance

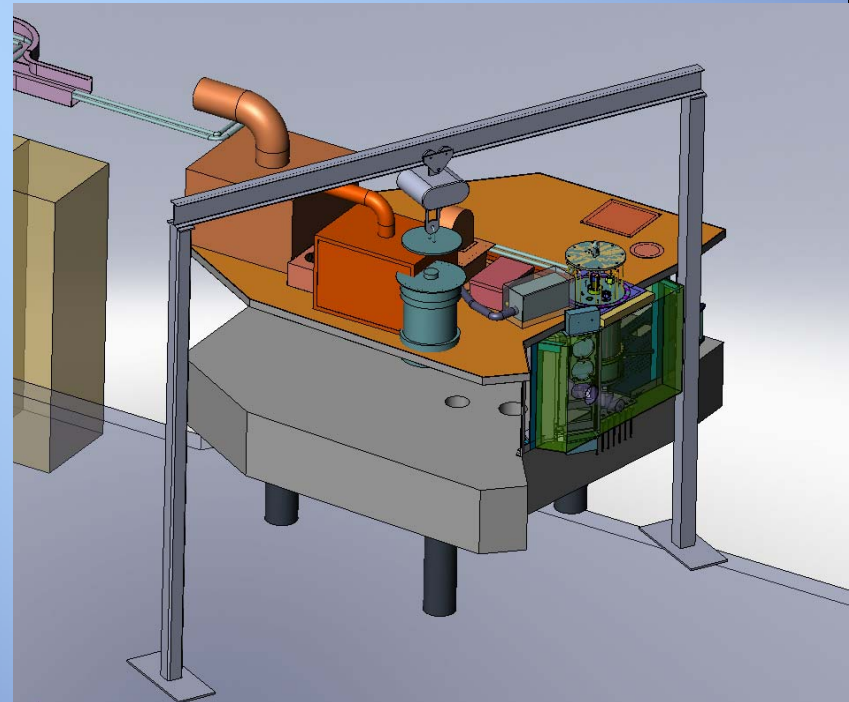
- Opto-mechanical system
  - Stages to be tested with lab PMAC system
- Camera system
  - Full optical testing will be performed (field lens through to detector)
  - Mechanical interface to focus stage provided by Caltech
  - Keywords tested
  - Data interface to RTC tested by Microgate
- Real-time control system
  - Modifications will be tested at Microgate on the spare controller with an interface to a Caltech-supplied emulator running the real camera code
  - Lab I&T at WMKO HQ: Repeat tests performed at Microgate + test interface to telemetry & to controls
- Controls
  - Motion control tested in lab
  - Keyword interface to RTC tested in lab with spare controller after return from Microgate
  - Keywords to camera tested
- Operations Software
  - Internal testing only prior to summit

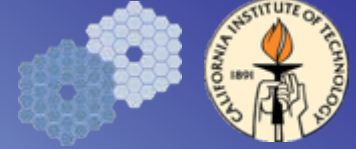




# Telescope I&T Sequence

- Bench mods to be performed before OSIRIS move in late Dec/11
- RTC installation & test
  - Install alongside existing RTC & verify same performance 1st
- Opto-mechanical & camera installation & test
- Controls software installation & test
- Operations software installation & test
- Interface testing
- Daytime system I&T
- On-sky I&T
- Performance characterization
- Science verification
- Commissioning & handover



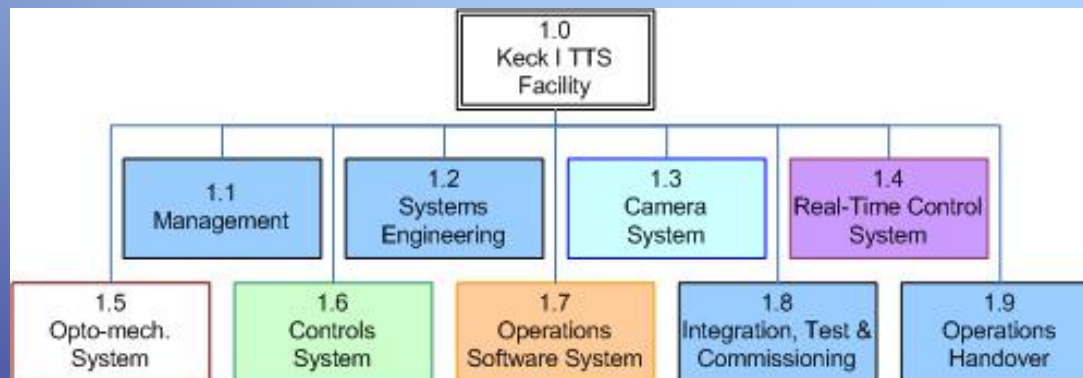
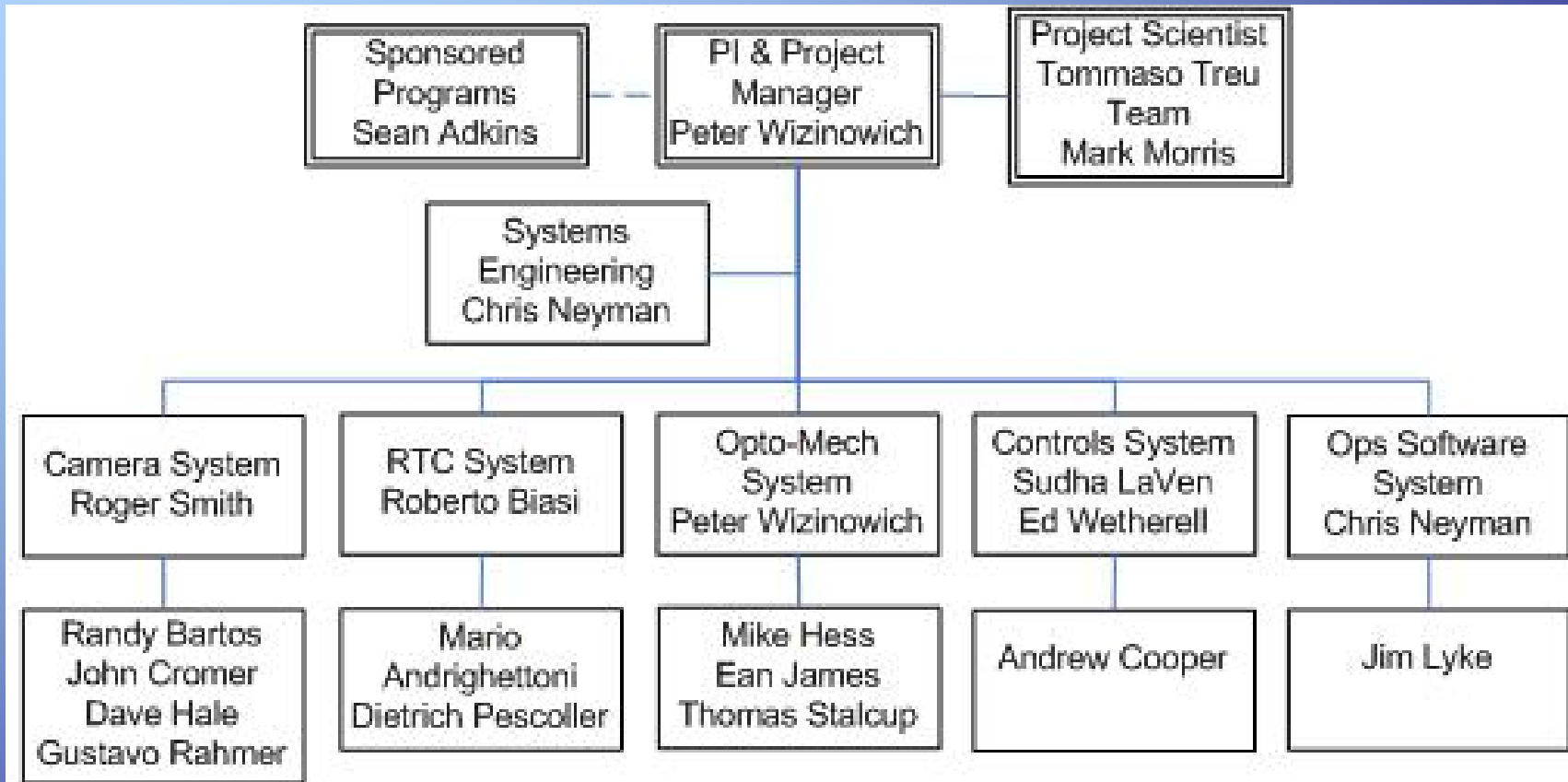


# Project Management

Peter Wizinowich  
WMKO

KAON 861

# Project Organization



# Project Milestones

<b>Milestone</b>	<b>Date in Proposal</b>	<b>Date in Current Plan</b>
Project Start	8/1/10	8/1/10
System Design Review	11/8/10	12/7/10
Preliminary Design Review	1/31/11	4/25/11
Detailed Design Review	7/11/11	8/30/11
RTC Pre-Ship Review		1/30/12
Camera Pre-Ship Review	7/9/12	9/28/12
Pre-Summit Review	11/9/12	1/30/13
Handover Review	7/3/13	12/15/13



# Project Plan

ID	WBS	Task Name	Camera	Work	2012				2013							
					Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4		
1	1.3	NIR TT Sensor Camera		4,665.4 hrs												
2	1.3.1	Camera Management		871 hrs												
38	1.3.2	Camera Systems Engineering		52 hrs												
46	1.3.3	Camera Emulator		96 hrs												
53	1.3.4	Camera Dewar		1,227 hrs												
54		Solid Model		96 hrs												
60		Bench Interface		14 hrs												
63		Vacuum System		550 hrs												
112		Optics		254 hrs												
118		Filter Wheel		207 hrs												
151		Cryostat Tip-tilt Ass'ly		76 hrs												
164		Installation Lifting Ass'ly		6 hrs												
168		Dewar design documentation		24 hrs												
169	1.3.5	Camera Electronics		378 hrs												
197	1.3.6	Camera Software		800 hrs												
198		DSP Software		364 hrs												
208	1.3.6	Host Software		436 hrs												
268	1.3.7	Camera Integration and Test		933.4 hrs												
319	1.3.8	Camera Commissioning Support		308 hrs												

ID	WBS	Task Name	DD	Work	April	May	June	July	August	September
					Apr	May	Jun	Jul	Aug	Sep
1	1	NIR TTS Detailed Design		1,525 hrs						
2	1.1	Project Management		355 hrs						
11	1.2	Systems Engineering		160 hrs						
23	1.3	Camera System		0 hrs						
24	1.4	Real-Time Control System Design		22 hrs						
27	1.5	Opto-mechanical System		428 hrs						
28	1.5.1	Optical Design and Documentation		138 hrs						
36	1.5.2	Mechanical Design & Documentation		290 hrs						
50	1.6	Controls System		229 hrs						
59	1.7	Operations Software System		241 hrs						
75	1.8	Integration, Test & Commissioning		54 hrs						
77	1.9	Operations Handover		36 hrs						



# Project Plan

ID	WBS	Task Name	FSD	Work	2012											
					Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1	1	Keck I TT Facility		2,483 hrs	[Gantt bar spanning all months]											
2	1.1	Project Management		256 hrs	[Gantt bar from Aug to Jun]											
12	1.2	Systems Engineering		110 hrs	[Gantt bar from Feb to Jun]											
23	1.3	Camera System		120 hrs	[Gantt bar from Aug to Jun]											
26	1.4	Real-time Control		152 hrs	[Gantt bar from Jul to Feb]											
31	1.5	Opto-mechanics		326 hrs	[Gantt bar from Aug to Dec]											
43	1.6	Controls		510 hrs	[Gantt bar from Aug to Mar]											
51	1.7	Operations Software		933 hrs	[Gantt bar from Oct to Apr]											
68	1.8	Integration, Test & Commissioning		32 hrs	[Gantt bar in May]											
70	1.9	Operations Handover		44 hrs	[Gantt bar in Jun]											

ID	WBS	Task Name	DC	Work	2012				2013				2014			
					Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	
1	1	Keck I TT Facility		2,242 hrs	[Gantt bar spanning all quarters]											
2	1.1	Project Management		142 hrs	[Gantt bar from Qtr 1 to Qtr 4]											
3	1.1.1	Planning & Tracking		32 hrs	[Gantt bar in Qtr 2]											
6	1.1.2	Meetings		110 hrs	[Gantt bar from Qtr 3 to Qtr 4]											
9	1.1.3	Milestones & Design Reviews		0 hrs	[Gantt bar from Qtr 1 to Qtr 4]											
10	1.1.3.1	Detailed Design Review		0 hrs	◆ 8/30											
11	1.1.3.2	TTF Sensor Pre-Ship Review		0 hrs	◆ 9/28											
12	1.1.3.3	Pre-Summit Review		0 hrs	◆ 1/30											
13	1.1.3.4	Readiness for 13B Shared Risk Review		0 hrs	◆ 2/1											
14	1.1.3.5	Handover Review		0 hrs	◆ 12/12											
15	1.1.3.6	TAC-allocated Science Starts		0 hrs	◆ 2/1											
16	1.2	Systems Engineering		60 hrs	[Gantt bar from Qtr 3 to Qtr 4]											
21	1.3	HQ Preparation		56 hrs	[Gantt bar in Qtr 4]											
24	1.4	Telescope Preparation		240 hrs	[Gantt bar from Qtr 1 to Qtr 2]											
27	1.5	Telescope I&T		1,416 hrs	[Gantt bar from Qtr 2 to Qtr 4]											
64	1.6	Commissioning and Handover		248 hrs	[Gantt bar in Qtr 3]											
72	1.7	Science Verification		80 hrs	[Gantt bar in Qtr 4]											



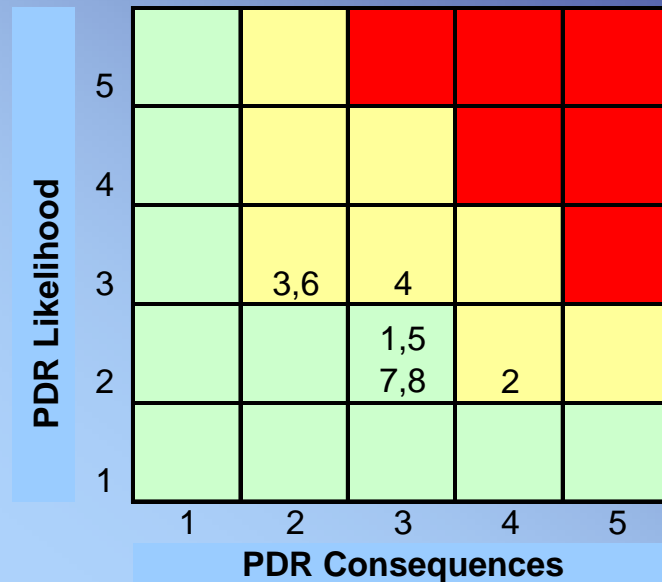
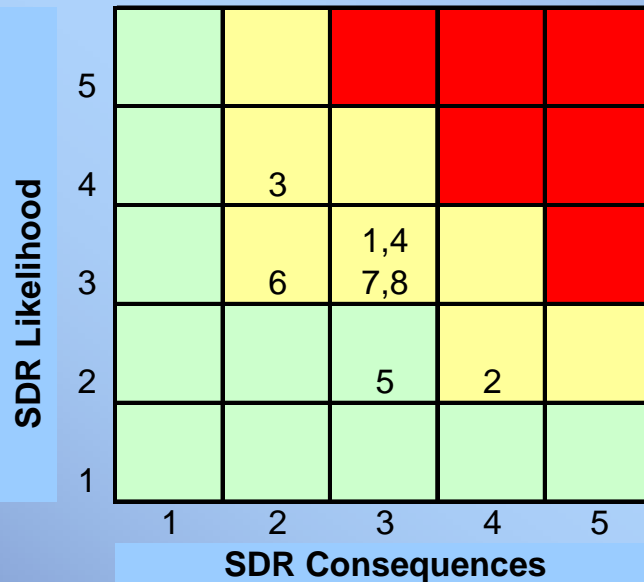


# Project Budget

Expenses	Title	Person Months	Notes	Year One	Thru SDR	Year Two	4/11/11	Year Three	Year Four	Total
				ACTUAL	10/01/10	Thru PDR		10/01/11	10/01/12	Revised Budget
				8/1/10 9/30/10	10/01/10 11/30/10	12/01/10 4/10/11	9/30/11	09/30/12	09/30/13	
<b>A. Senior Personnel</b>										
P. Wizinowich	Principal Investigator	2.4		\$ 4,239	\$ 9,930	\$ 24,490	\$ 17,170	\$ 19,311	\$ 6,866	\$ 82,006
T. Stalcup	Project Manager	15		\$ 670	\$ 5,359	\$ 6,200	\$ 6,081	\$ -		\$ 18,311
<b>( 2 ) Total Senior Personnel</b>		<b>18</b>	<b>1</b>	<b>\$ 4,909</b>	<b>\$ 15,289</b>	<b>\$ 30,690</b>	<b>\$ 23,251</b>	<b>\$ 19,311</b>	<b>\$ 6,866</b>	<b>\$ 100,316</b>
<b>B. Other Personnel</b>										
( 0 ) Post Doctoral Associates				\$ -			\$ -	\$ -	\$ -	\$ -
( 9 ) Other Professionals		23	1	\$ 4,922	\$ 8,221	\$ 59,844	\$ 49,304	\$ 129,349	\$ 110,699	\$ 362,340
( 0 ) Graduate Students				\$ -			\$ -			\$ -
( 0 ) Undergraduate Students				\$ -			\$ -			\$ -
( 1 ) Secretarial - Clerical (If Charged Directly)			1	\$ -	\$ -	\$ 1,202	\$ 1,202	\$ 546	\$ -	\$ 2,950
( 0 ) Other				\$ -						\$ -
<b>Total Salaries and Wages</b>				<b>\$ 9,831</b>	<b>\$ 23,510</b>	<b>\$ 91,736</b>	<b>\$ 73,758</b>	<b>\$ 149,206</b>	<b>\$ 117,565</b>	<b>\$ 465,606</b>
C. Fringe Benefits			2	\$ 2,320	\$ 6,066	\$ 23,668	\$ 19,029	\$ 38,048	\$ 29,943	\$ 119,073
<b>Total Salaries, Wages and Fringe Benefits</b>				<b>\$ 12,151</b>	<b>\$ 29,576</b>	<b>\$ 115,404</b>	<b>\$ 92,787</b>	<b>\$ 187,254</b>	<b>\$ 147,508</b>	<b>\$ 584,679</b>
<b>D. Equipment</b>										
H2RG detector				\$ -	\$ 250,000				\$ -	\$ 250,000
ARC SDSU-III readout electronics				\$ -	\$ 6,000	\$ 7,000		\$ 8,500		\$ 21,500
Microgate RTC modifications				\$ -		\$ 16,950	\$ 10,170	\$ 40,680		\$ 67,800
Dewar optics				\$ -			\$ -	\$ 21,500		\$ 21,500
Dichroic beamsplitter				\$ -			\$ -	\$ 10,000		\$ 10,000
Pickoff optics stage				\$ -			\$ -	\$ 7,000		\$ 7,000
Focus stage				\$ -			\$ -	\$ 9,200	\$ -	\$ 9,200
<b>Total Equipment</b>				<b>\$ -</b>	<b>\$ 256,000</b>	<b>\$ 23,950</b>	<b>\$ 10,170</b>	<b>\$ 96,880</b>	<b>\$ -</b>	<b>\$ 387,000</b>
<b>E. Travel</b>										
Domestic			3	\$ -		\$ 315	\$ -	\$ 4,400	\$ -	\$ 4,715
Foreign				\$ -			\$ -	\$ -	\$ -	\$ -
F. Other Supplies				\$ -			\$ -	\$ -	\$ -	\$ -
<b>G. Other Direct Costs</b>										
1. Materials and Supplies				\$ 331	\$ 44	\$ 852	\$ 1,000	\$ 21,845	\$ 500	\$ 24,572
2. Publication Costs/Documentation/Dissemination				\$ -			\$ -	\$ -	\$ -	\$ -
3. Consultant Services				\$ -		\$ 8,840	\$ 20,800	\$ -	\$ -	\$ 29,640
4. Computer Services				\$ -	\$ -	\$ 38	\$ -	\$ -	\$ -	\$ 38
5. Subawards	CIT		4	\$ -	\$ -	\$ 112,105	\$ 109,755	\$ 340,781	\$ -	\$ 562,640
6. Other				\$ -			\$ -	\$ -	\$ -	\$ -
<b>Total Other Direct Costs</b>				<b>\$ 331</b>	<b>\$ 44</b>	<b>\$ 121,835</b>	<b>\$ 131,555</b>	<b>\$ 362,626</b>	<b>\$ 500</b>	<b>\$ 616,890</b>
<b>H. Total Direct Costs</b>				<b>\$ 12,482</b>	<b>\$ 285,620</b>	<b>\$ 261,503</b>	<b>\$ 234,512</b>	<b>\$ 651,159</b>	<b>\$ 148,008</b>	<b>\$ 1,593,285</b>
<b>I. Indirect Costs (F&amp;A)</b>										
Modified total direct costs (Base)			5	\$ 12,482	\$ 29,620	\$ 150,449	\$ 114,587	\$ 70,319	\$ 117,143	\$ 494,599
Rate		60.00%		\$ 6,865	\$ 19,891	\$ 67,431	\$ 90,096	\$ 42,191	\$ 70,286	\$ 296,759
<b>Total Indirect Costs</b>				<b>\$ 6,865</b>	<b>\$ 19,891</b>	<b>\$ 67,431</b>	<b>\$ 90,096</b>	<b>\$ 42,191</b>	<b>\$ 70,286</b>	<b>\$ 296,759</b>
<b>J. Total Direct and Indirect Costs</b>				<b>\$ 19,347</b>	<b>\$ 305,511</b>	<b>\$ 328,934</b>	<b>\$ 324,607</b>	<b>\$ 693,351</b>	<b>\$ 218,294</b>	<b>\$ 1,890,044</b>
WMKO cost share available							\$ 15,000	\$ 28,000	\$ 240,000	\$ 283,000
WMKO cost share applied								\$ 143,180	\$ 30,865	\$ 174,045
Revised Proposal Funding Profile				\$ 314,511			\$ 715,613	\$ 498,447	\$ 187,429	\$ 1,716,000
Budget (Proposal + WMKO) - Plan				\$ 295,164			\$ 51,724	\$ 0	\$ 1	\$ 108,956



# Risk Assessment



- ↓ 1. Measurement accuracy not achieved off null
- 2. Advantages of NIR TTS not achieved
- ↓ 3. Schedule delays due to personnel non-availability
- 4. Inadequate contingency (10.6% currently)
- 5. Detector failure
- 6. Conflicts with observing schedule impacting schedule
- ↓ 7. Camera data interface to RTC doesn't work
- ↓ 8. Self heating doesn't allow shifting ROIs



# Reviewer Topics

## 5) Overall complexity of the system

- In particular the number of ROIs
- Consider descoping implementation & commissioning, but implementing all the hooks (design) for future implementation &/or commissioning

## Response:

- The number of ROIs is 1 from the system implementation & commissioning perspective
- The number of ROIs is larger from the RTC & camera perspectives since we want the appropriate hooks in place for future implementation & commissioning
- We have taken a similar approach elsewhere (e.g., the future capability of implementing better optimization tools) by having the hooks in place as part of the RTC & camera, but not investing further WMKO resources as part of this project (unless we have remaining dollars)



# Reviewer Topics

## 6) Very tight schedule for the detailed design

- Considering the amount of work to be done in a short period & still a low contingency

### Response:

- The schedule is tight but we think that it is reasonable now that the team is ramped up & already working on the DD
- Our DD phase work estimates & personnel availabilities are consistent with the tight schedule (WMKO personnel < 55% usage during DD)
- A tight schedule offers an opportunity to control costs by keeping people focused on the deliverables



# Reviewer Topics

## 7) Impact of other projects & personnel availability

- Delays in other Keck projects (K1 free space transport (FST), OSIRIS relocation) & availability of key people may impact the next phase, & the development & commissioning

### Response:

- The K1 FST & K2 center launch projects have higher priorities so they could impact the NIR TTS DD phase schedule
- Neyman is the key NIR TTS person that will be needed on K1 FST due to Stalcup's departure.
  - 77 working days between PDR & DDR assuming 10 vacation days.
  - Neyman needed ~30 days on FST over this period & ~5 days on PSF-R.
  - Neyman has the most DD phase work with 337h = 42 days.



# In Conclusion

- We feel that we are ready to move into the DD phase of this project.
  - Careful attention will need to be paid to the contingency
- The reviewer input (topics & RIX) has already proven to be helpful, as doubtlessly will be the reviewer report. We will make use of these in the DD.
- Thanks to all the reviewers & contributors.

