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 Andrighettoni, 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 OOCD & 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. Descopes 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.

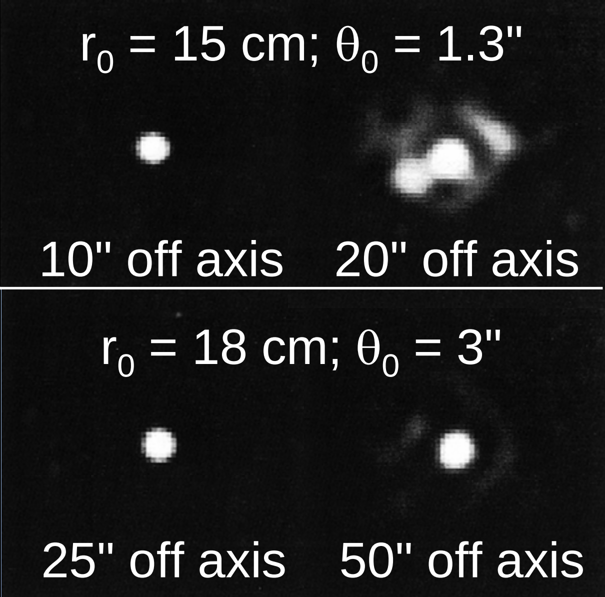
Requirements, Interfaces & Compliance

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

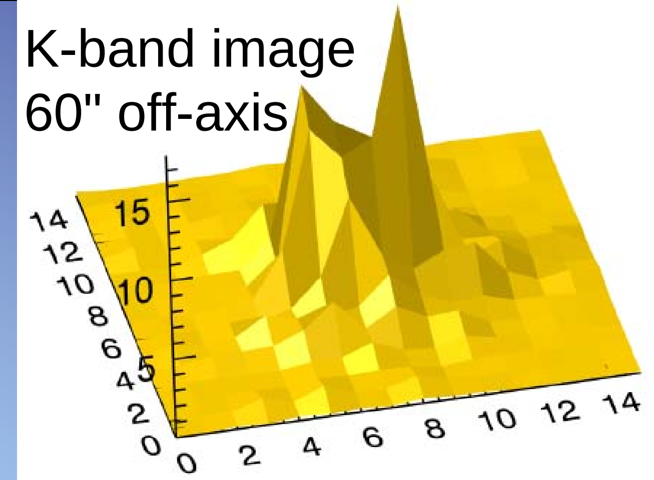
Performance Analysis



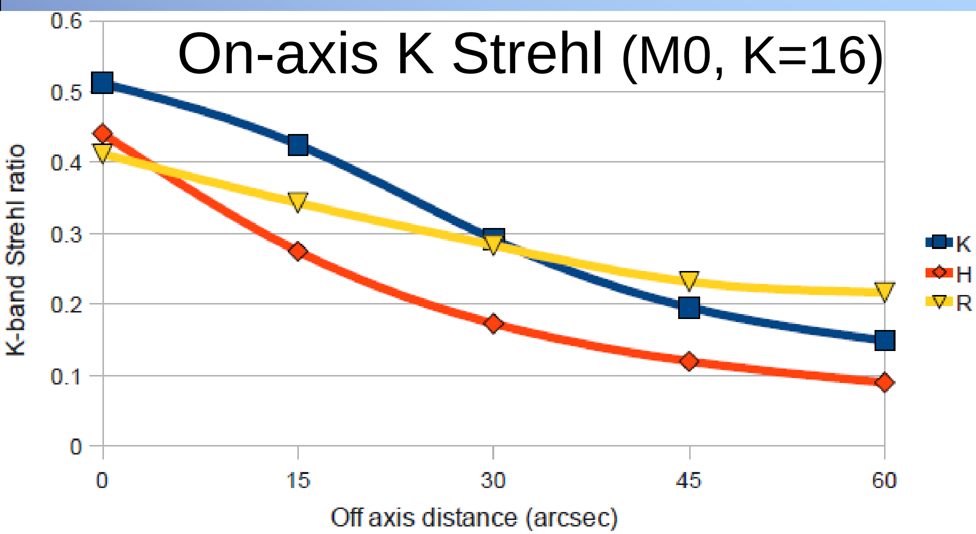
λ = 1.45 μm, D = 8 m

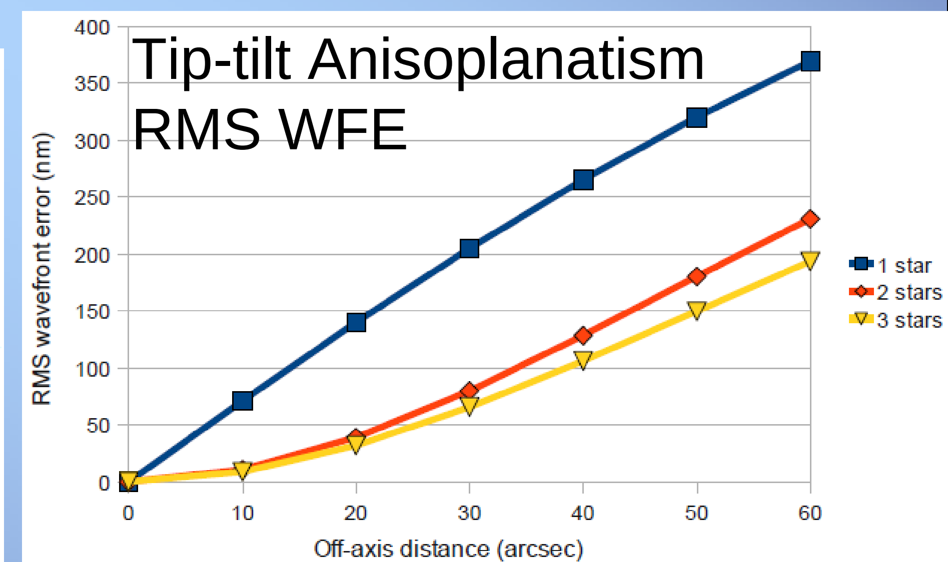
Sandler et al. 1994

Median Mauna Kea isoplanatic angle = 2.7"



Van Dam 2011





100 nm → 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 → R = 18.5 (or for H = 16 → 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.
- 1st 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

Operations Software System
- Pre-Observing Tools
- Observation Setup
- Calibration
- User Interface
- Observing Tools

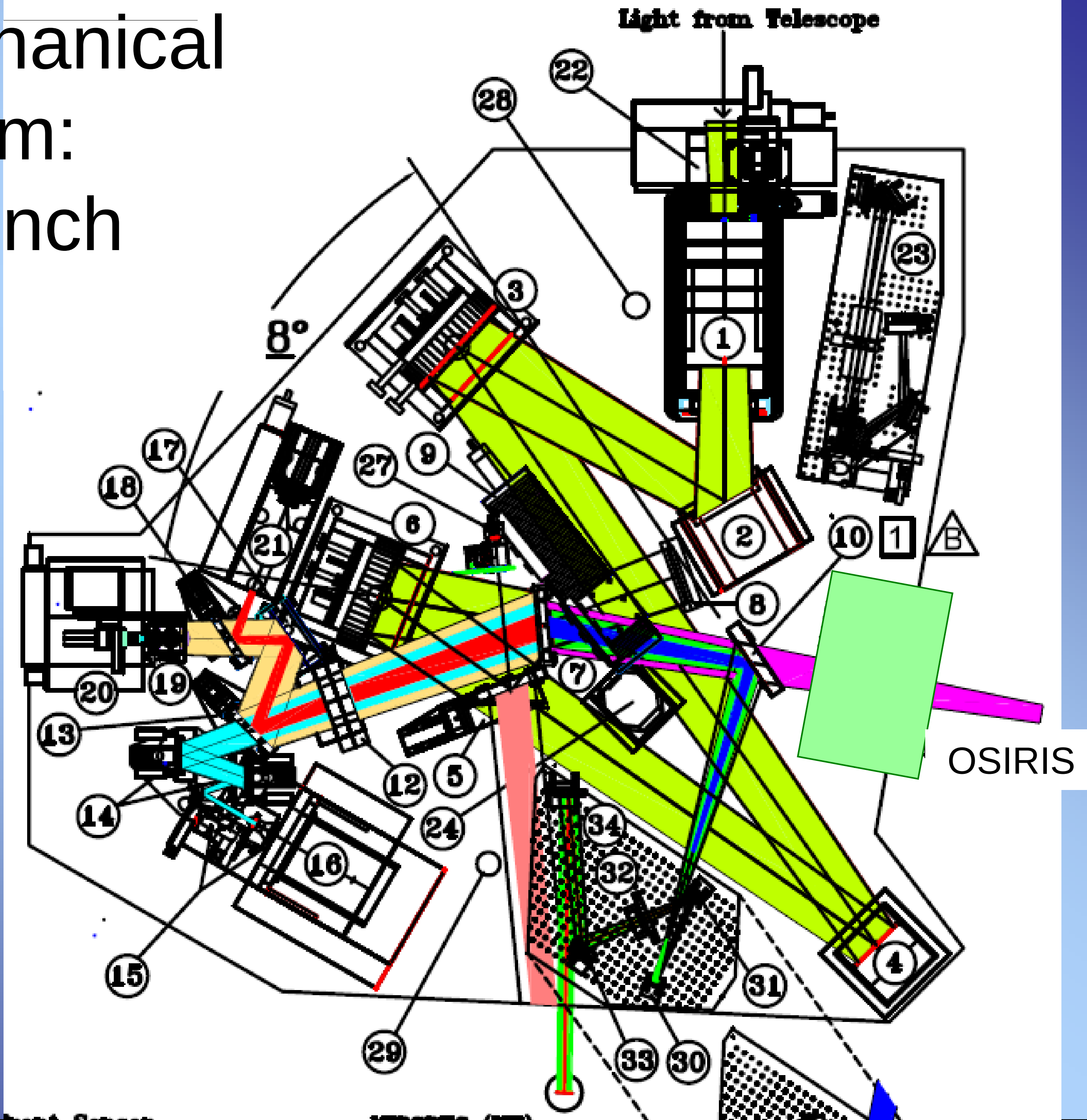
Controls System
- Pickoff & Focus Motion Control
- Camera Device Control
- Supervisory Controller Modifications

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

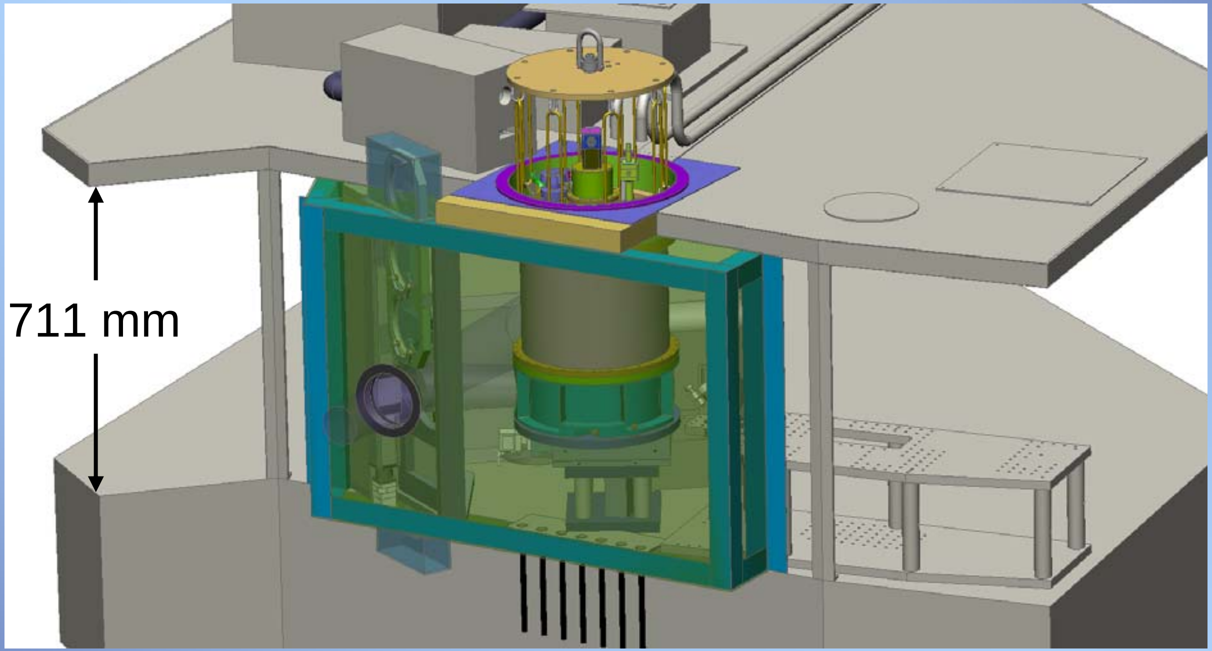
Real-Time Control System
- Camera Data Processing
- TT Determination
- Telemetry Input Mods

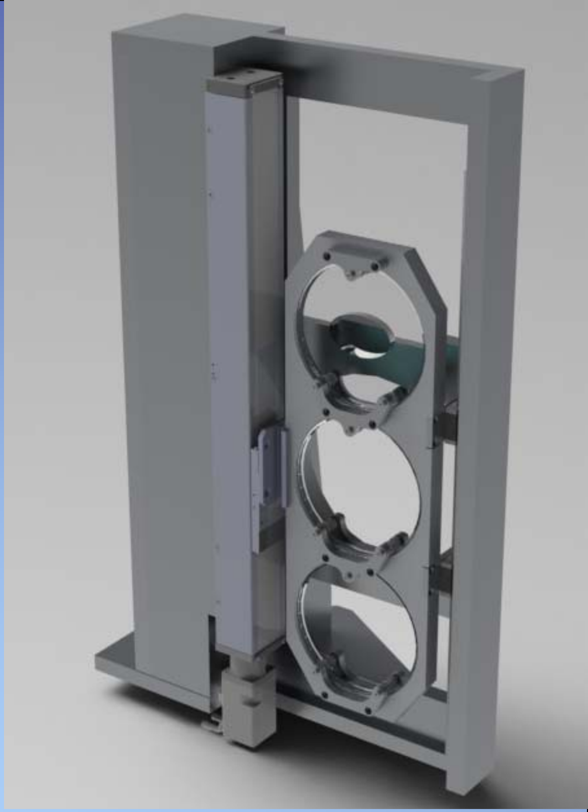
Opto-Mechanical System
- Pickoff Exchange Mechanism
- Focus Mechanism
- Mods to AO bench

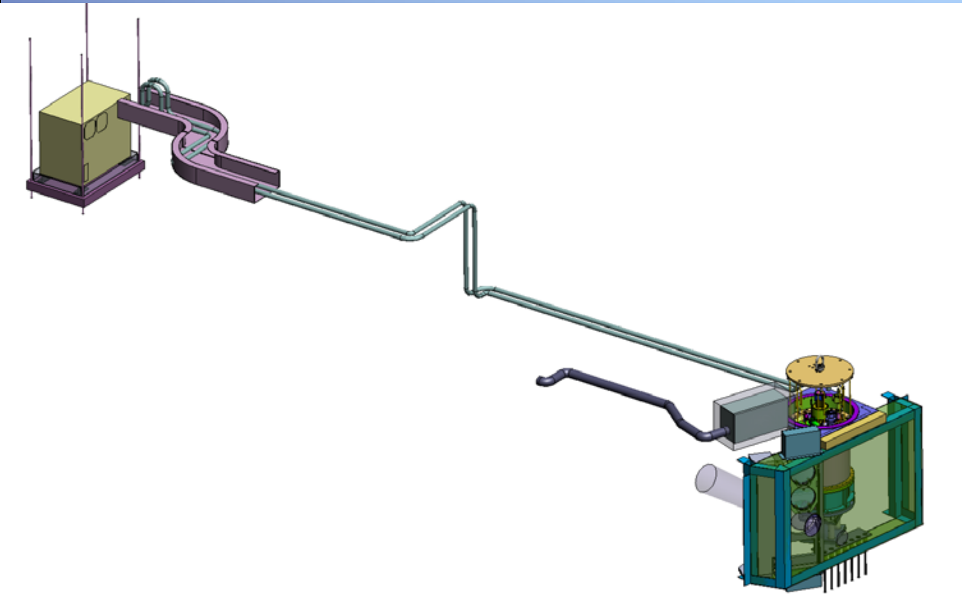
Opto-Mechanical System: AO Bench

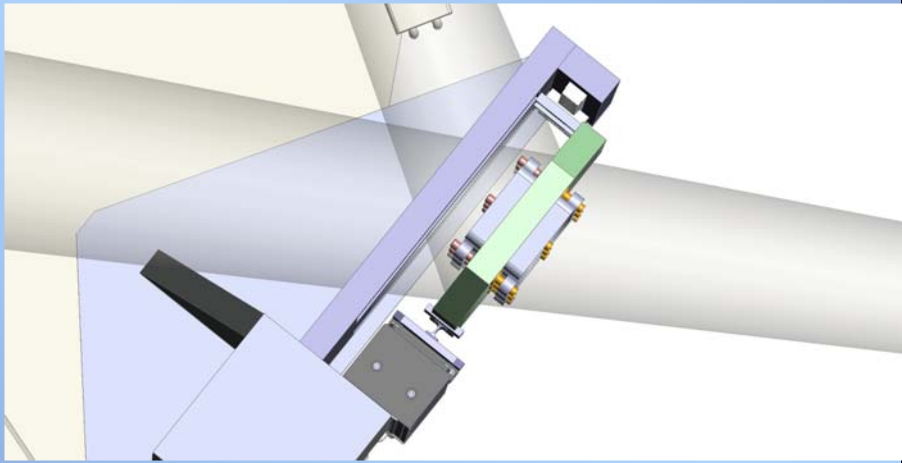


Opto-Mechanical System

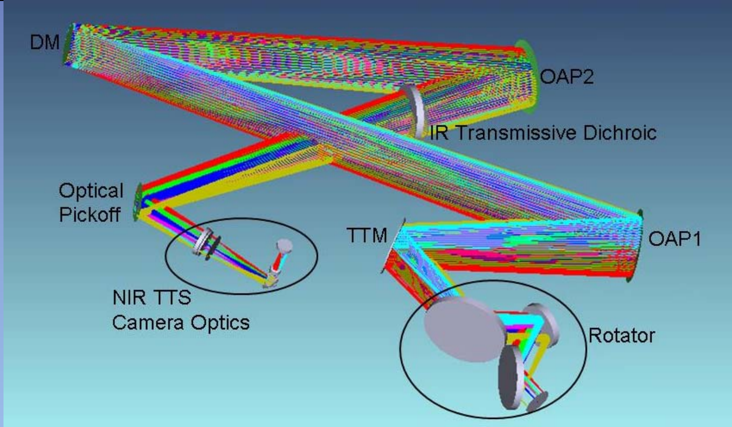




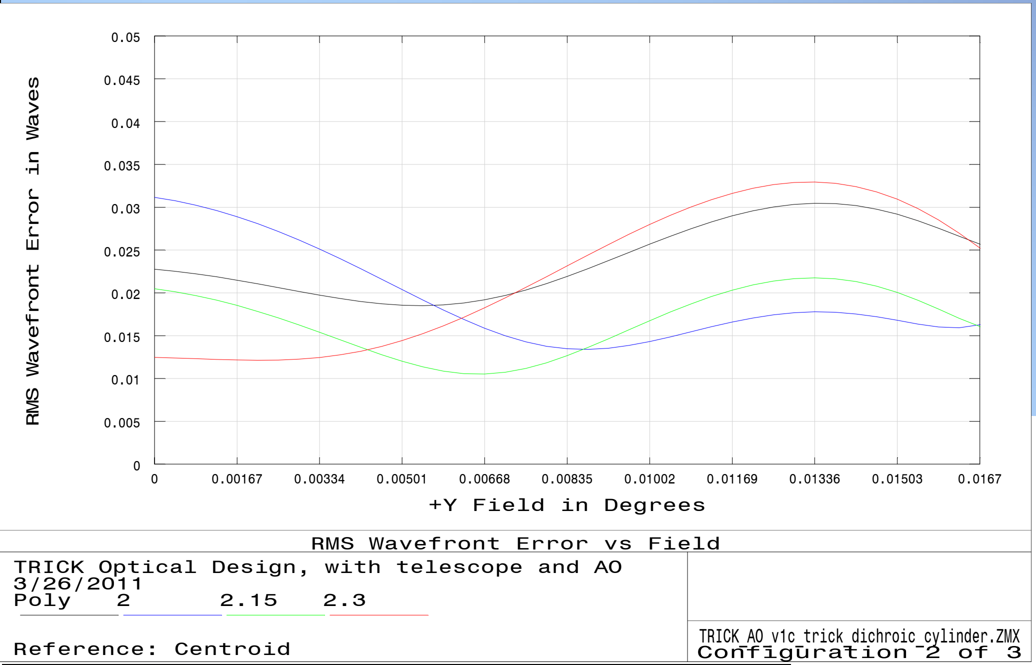


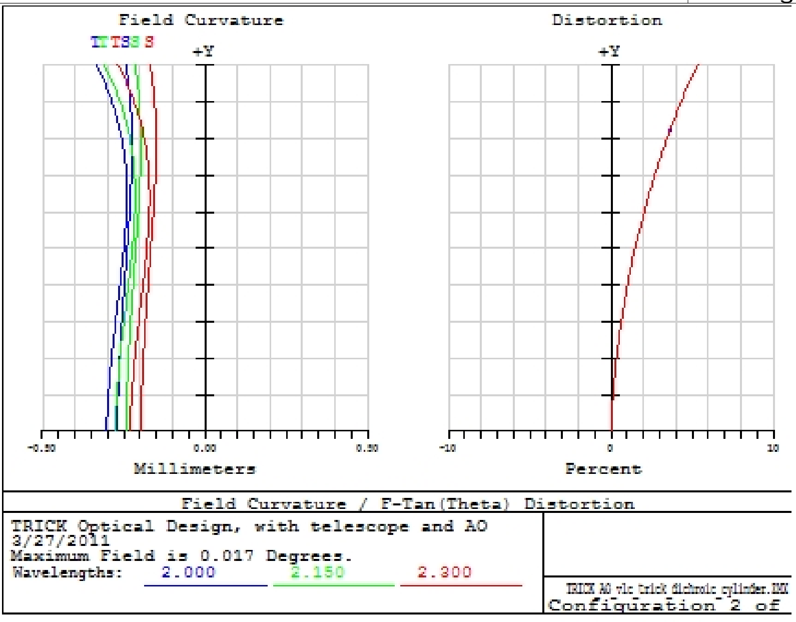


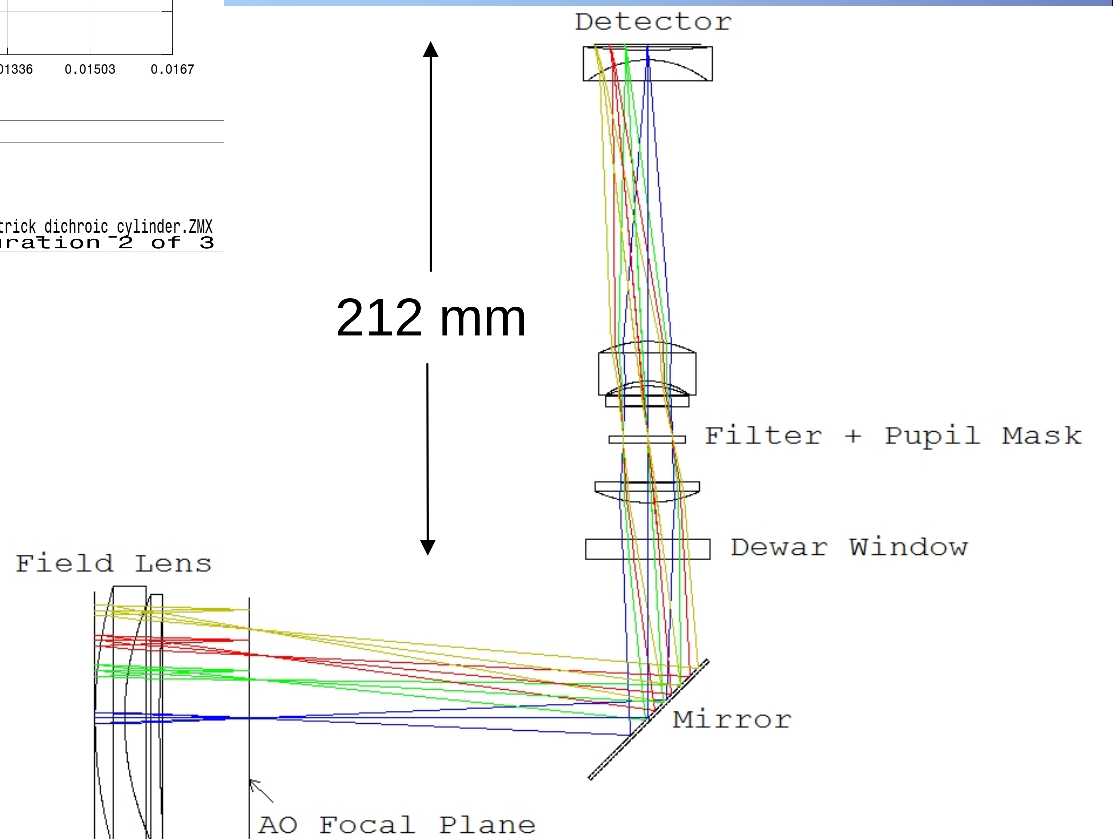
Opto-Mechanical System



H & Ks Strehls 95 to 97% over field







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 μm, decenter to 50 μm, tilt to 0.1°
- Result: 90% better than 72% Strehl (50% better than 84%)

Element	Radius (%)	Thickness (mm)	Decenter (mm)	Tilt (deg)
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

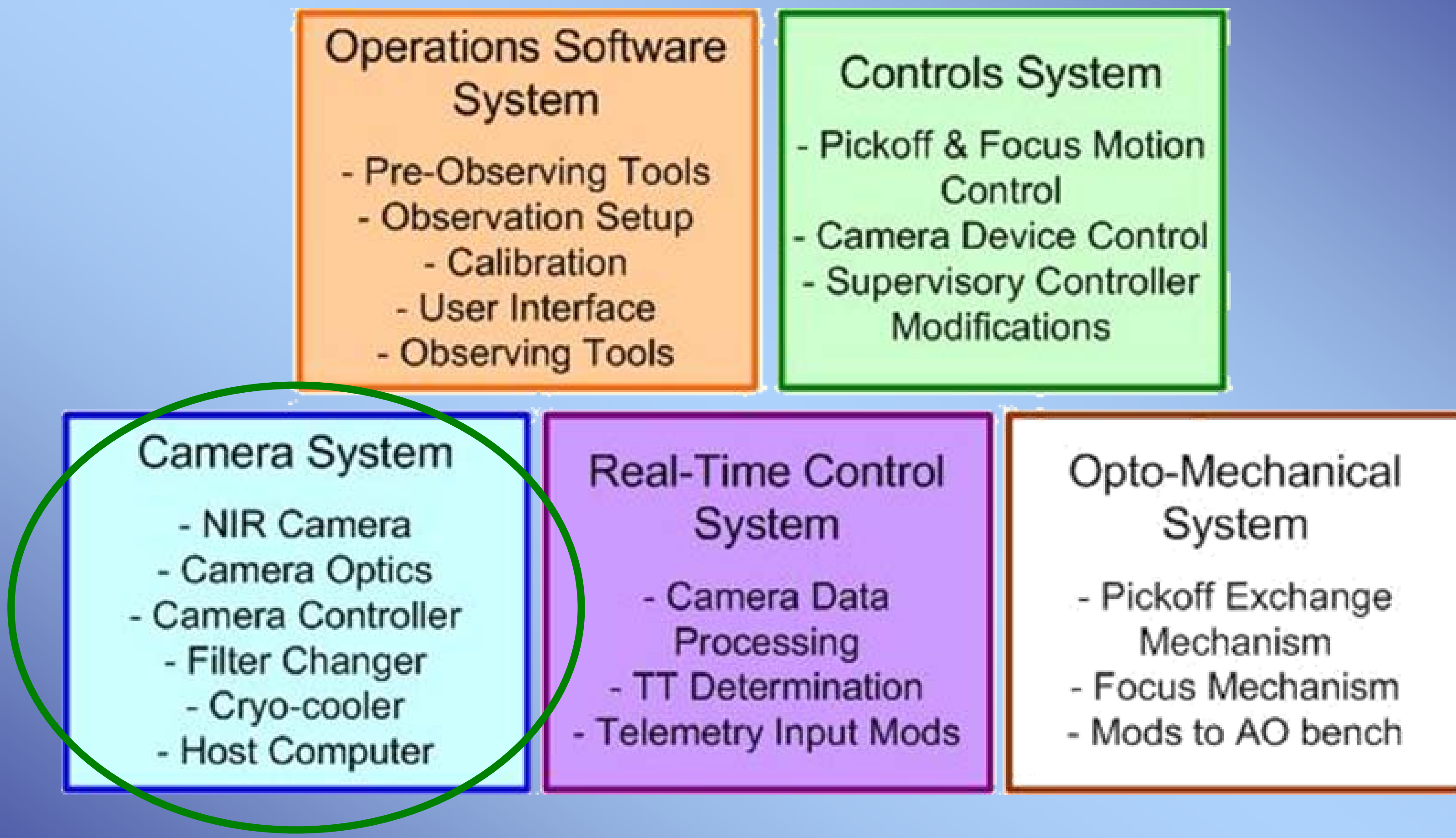
Response:

- 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.

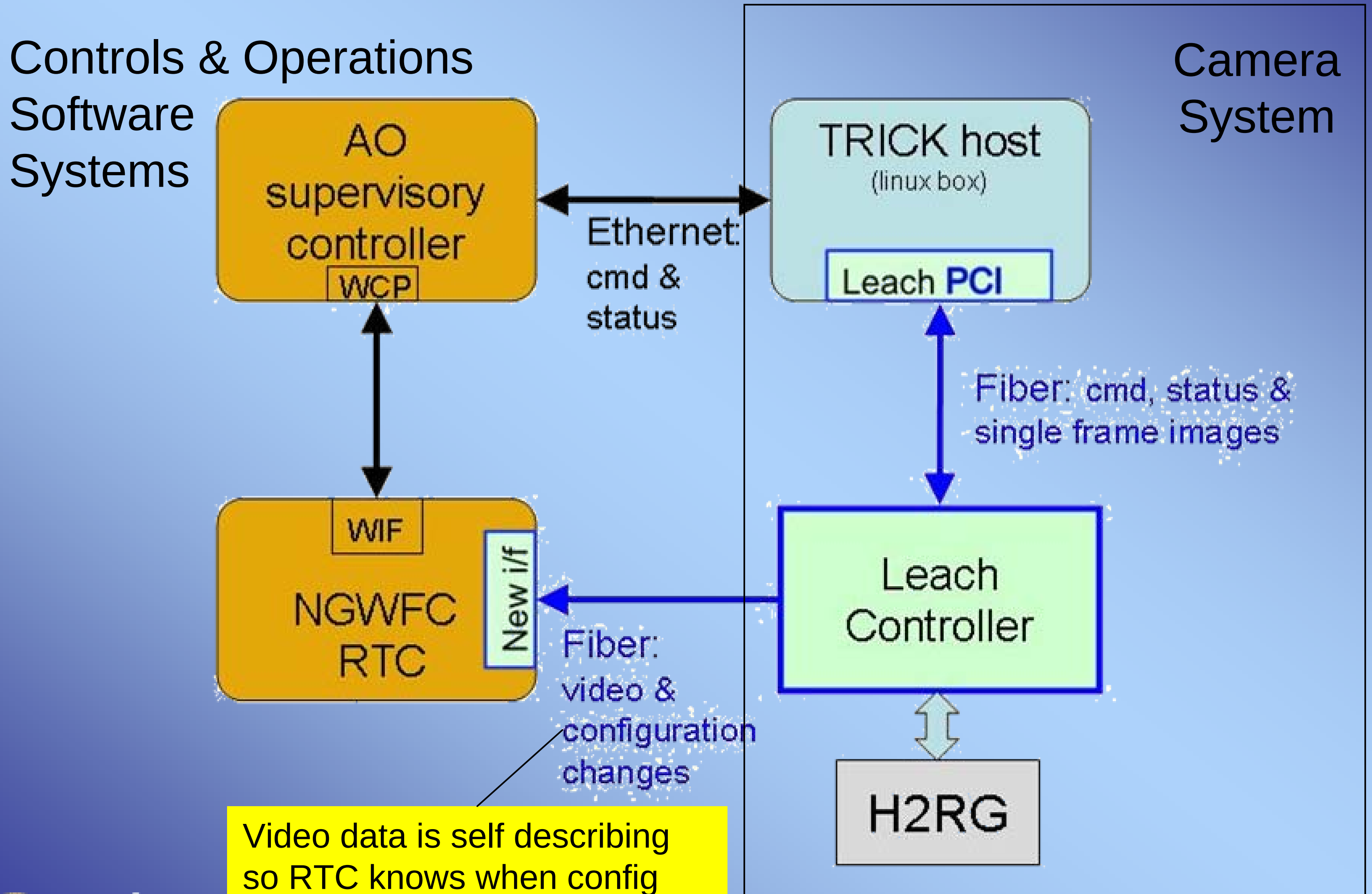
Camera System Design

Roger Smith
Caltech

Design Overview - Subsystems



Communication Interfaces



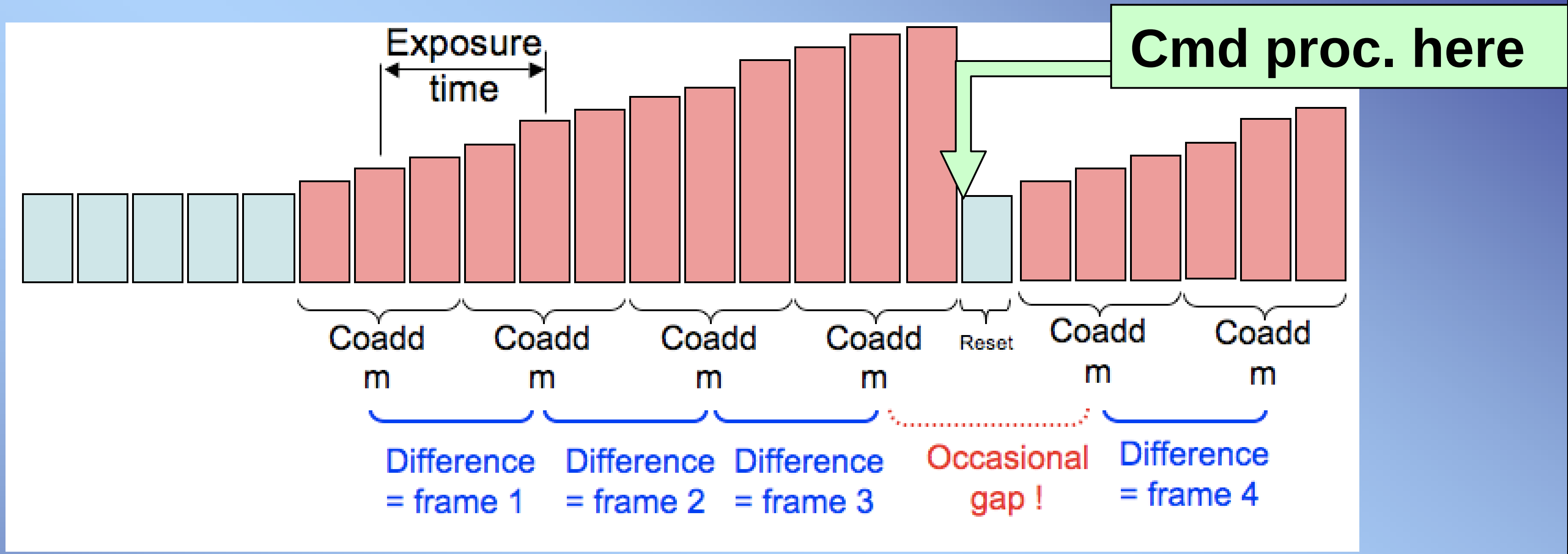
Video data is self describing so RTC knows when config changes occur, without tight timing through TRICK host.

Data Products

- Via TRICK host (FITS files):
  - Full frame, 4ch CDS readout, for acquistion. 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 (140µs), 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 √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 3rd iteration

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

A B A B A B C A B A B A B C A B A B A B C D A B A B A B C …

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:

K	00	CC	P1	T1	X1	Y1	DX1	DY1	P2	T2	X2	Y2	DX2	DY2	Pn	…

ctrl code

header

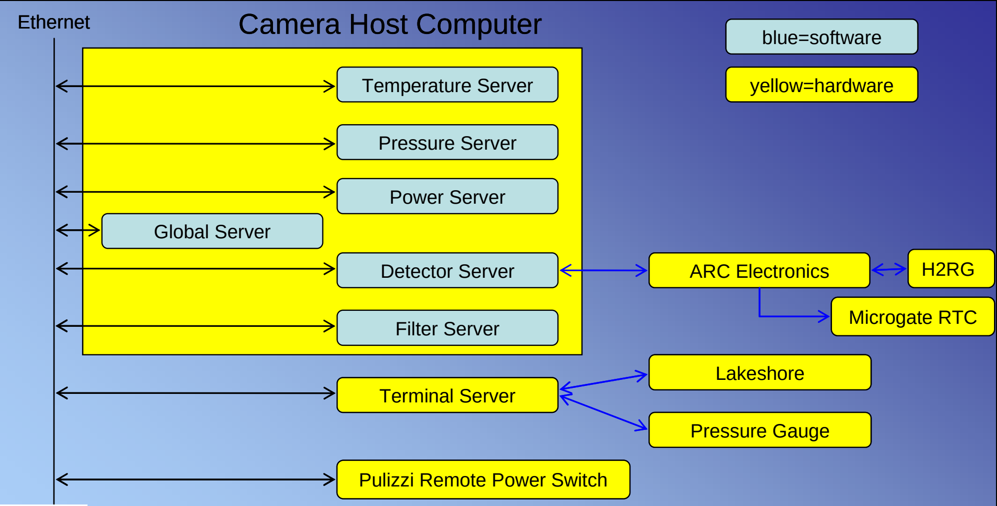
config counter (followed by ROI table)

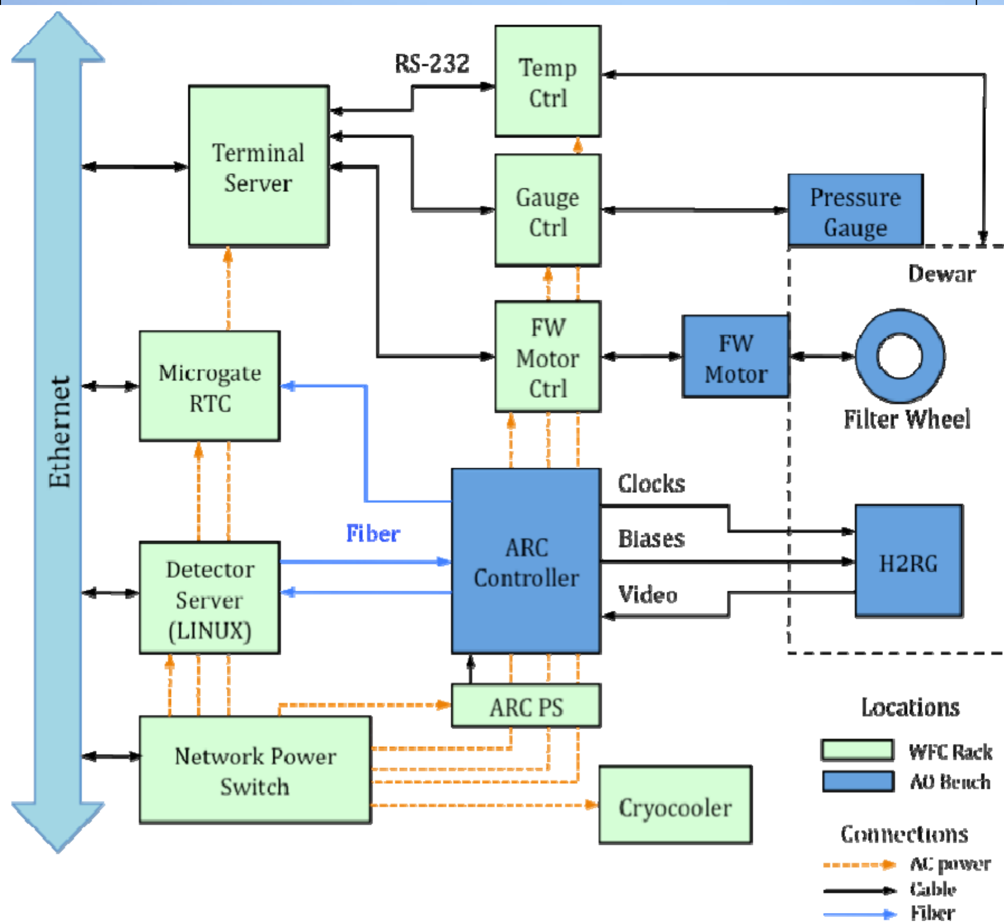
- data packet example (for two 2x2 ROIs, P1=1 and P2=2):

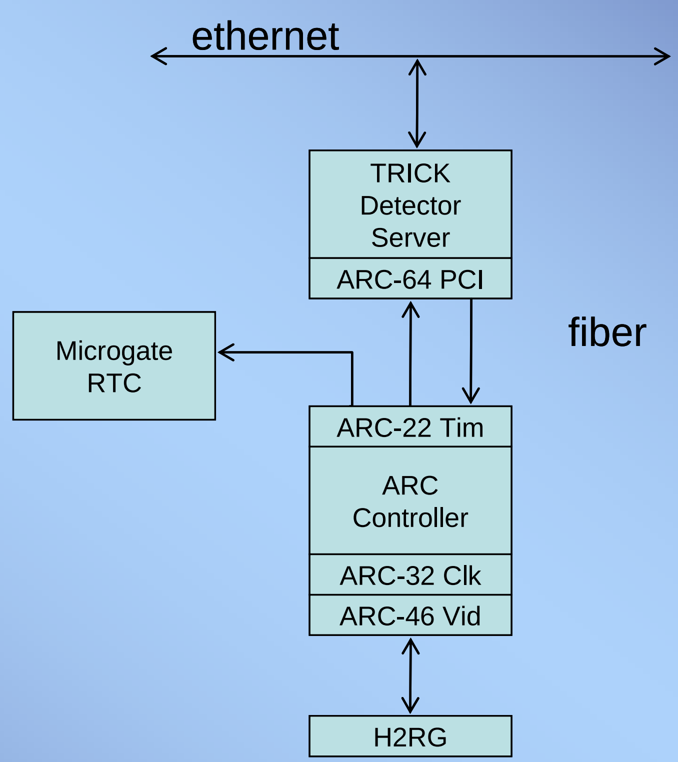
K	01	pp	pp	pp	pp	K	01	pp	pp	pp	pp	K	02	pp	pp	…

pixel values

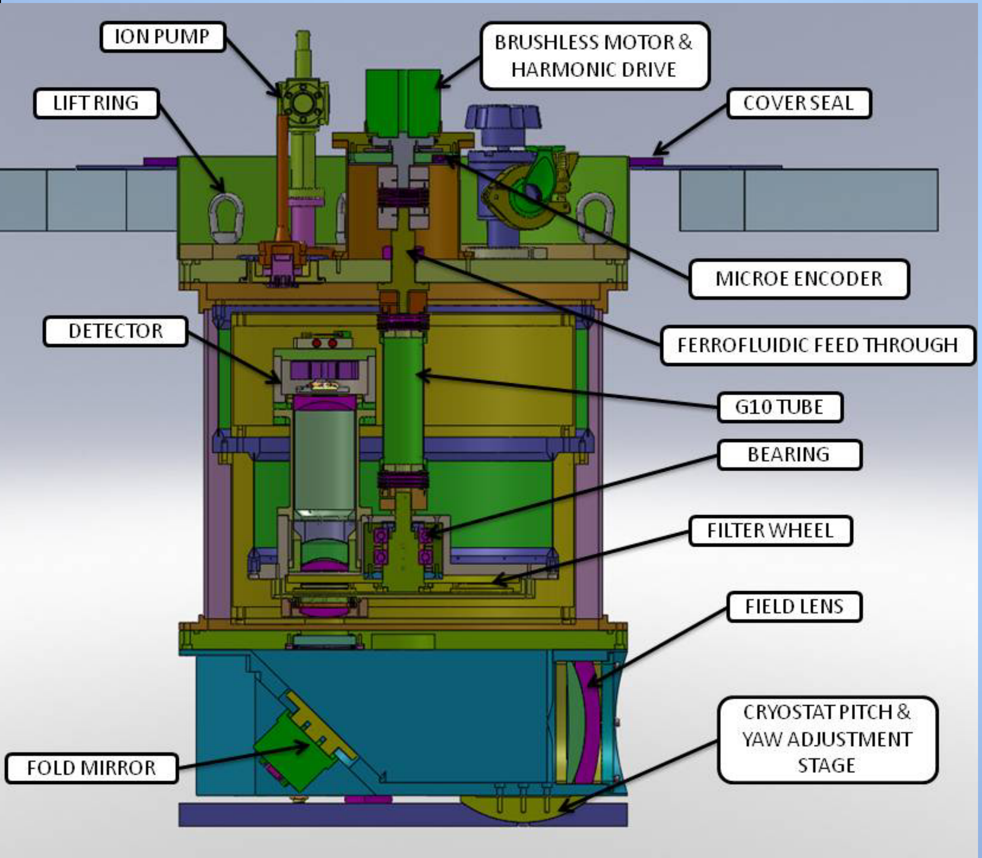
Camera Hardware & Servers

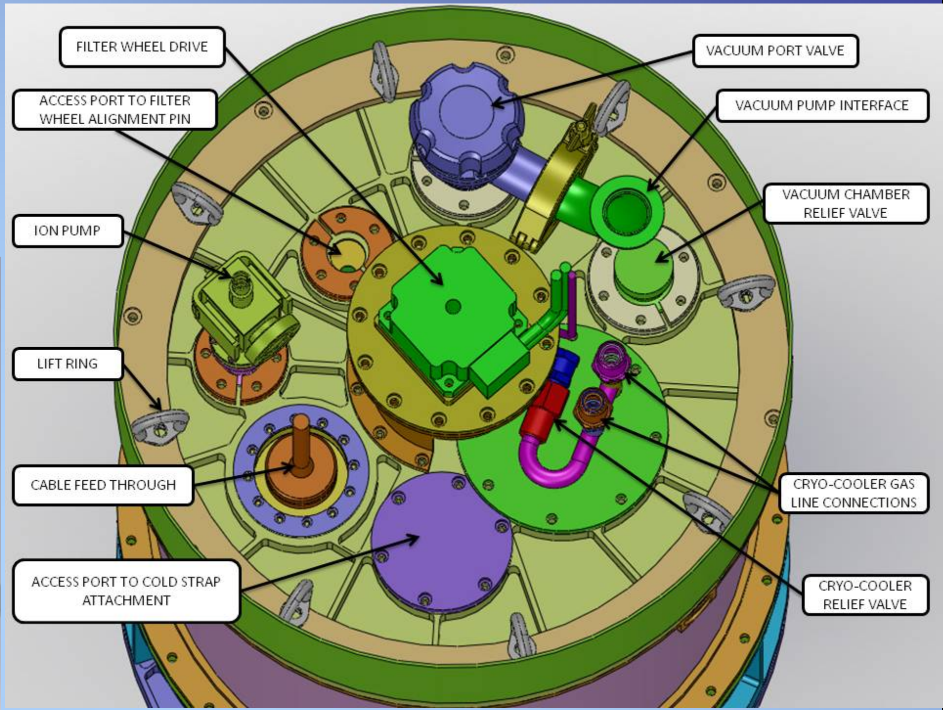




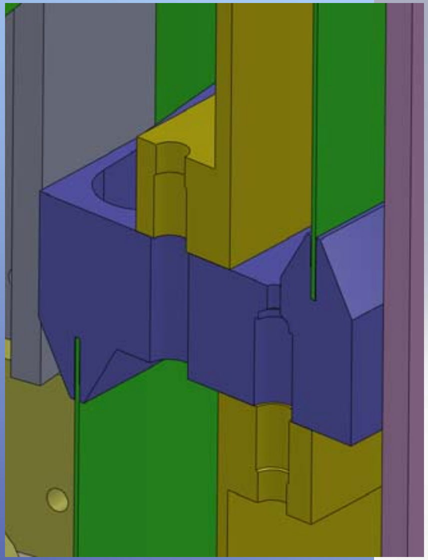


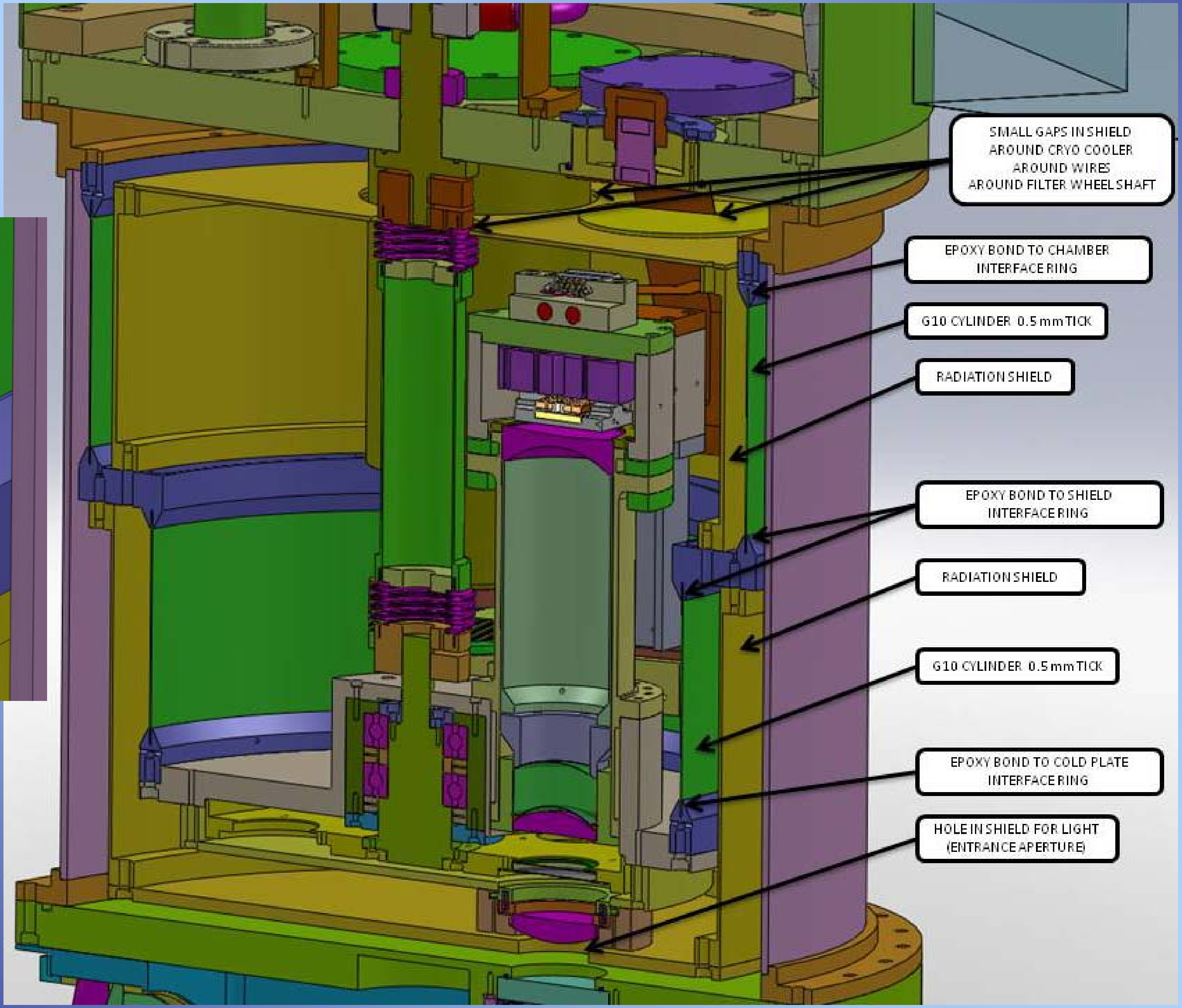
Camera Dewar





INTERNAL SUPPORTS AND RADIATION SHIELD





MASS BREAKDOWN

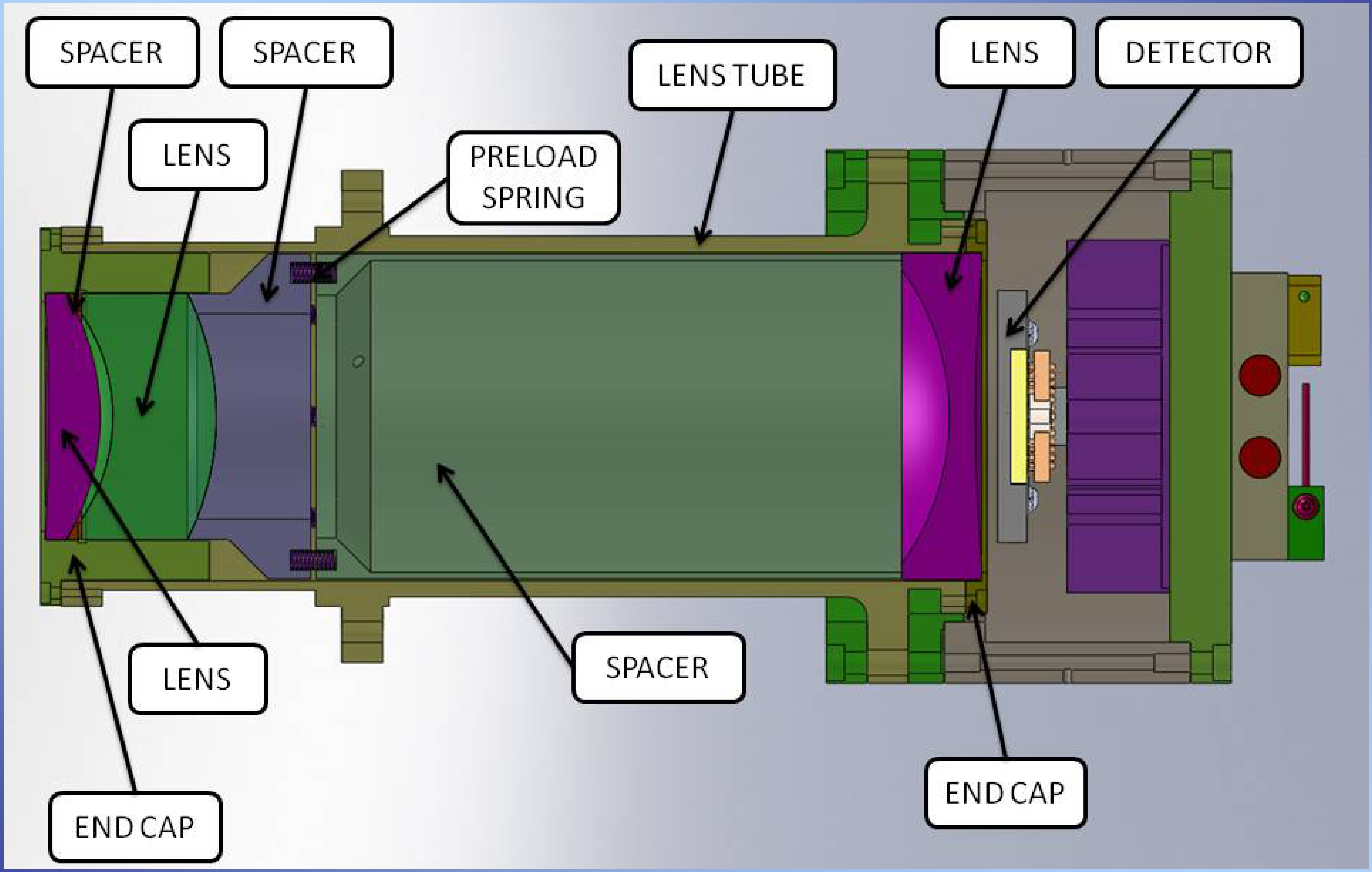
RIQ-CBO3: Is there a plan to do a flexure analysis of the TRICK system during DD and also to check the impacts on AO bench?

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.

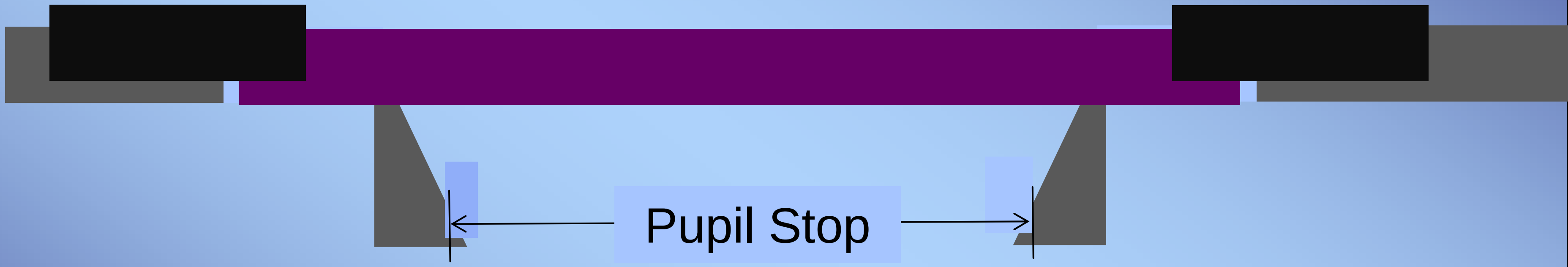
	current	light-weighted	~ cost
Top cover	9.72 lb	5.26 lb	$1.5K
Bottom cover	9.37 lb	3.5 lb	$ 2K
Cold plate	3.5 lb	2.8 lb	$500
Base	24.5 lb	17.5 lb	$1.5K

LENS MOUNTING



Filter Pupil Mounting

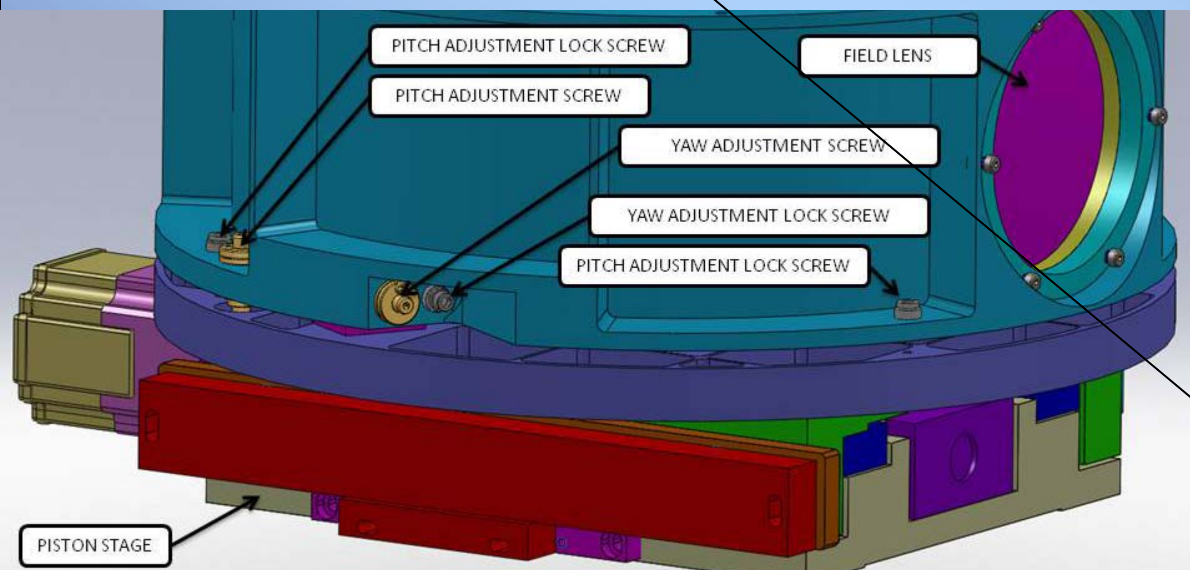
RIQ-RDC6: It's not clear to me how the filters/pupil stops will be mounted? What material will be used. Is there any mechanical design work done yet for the filter holders/pupil masks. I'm concerned about restraining the filters without possible coating damage to the filters.

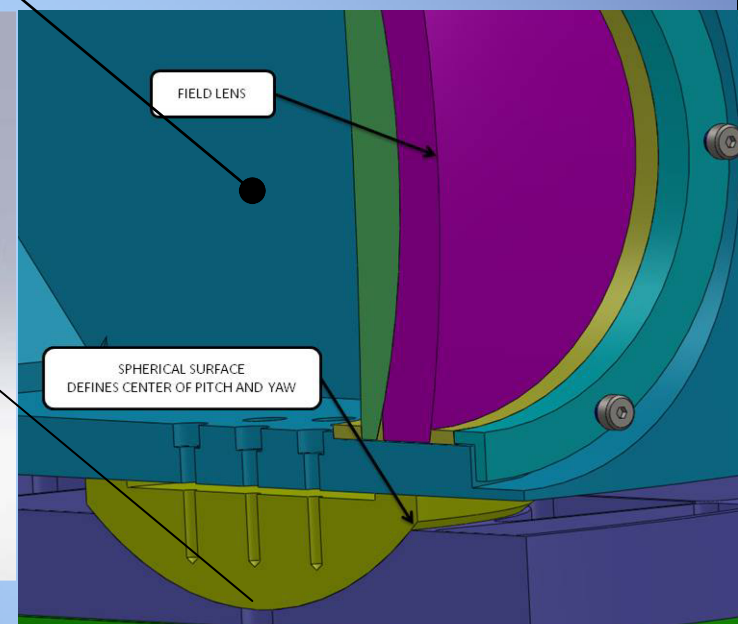


- Contact made outside optical path.
- Precise pupil stop machined into filter wheel itself, for best repeatability and minimal radial position variation from filter to filter.
- Tangential position errors will be corrected with drive system.

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).



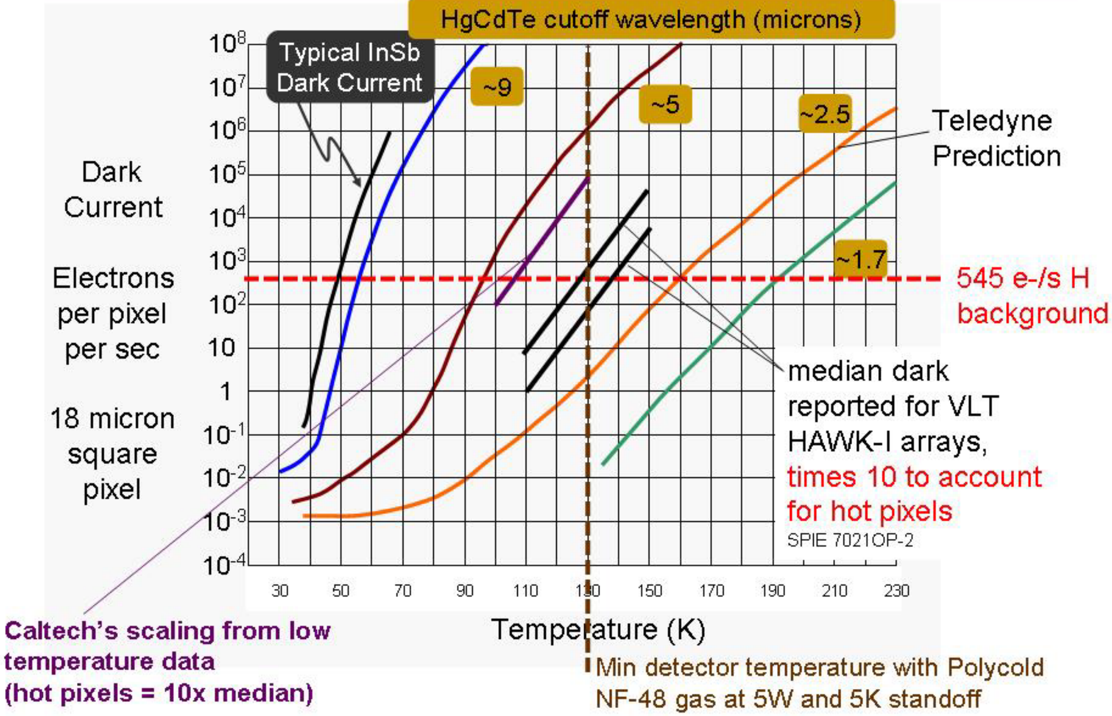


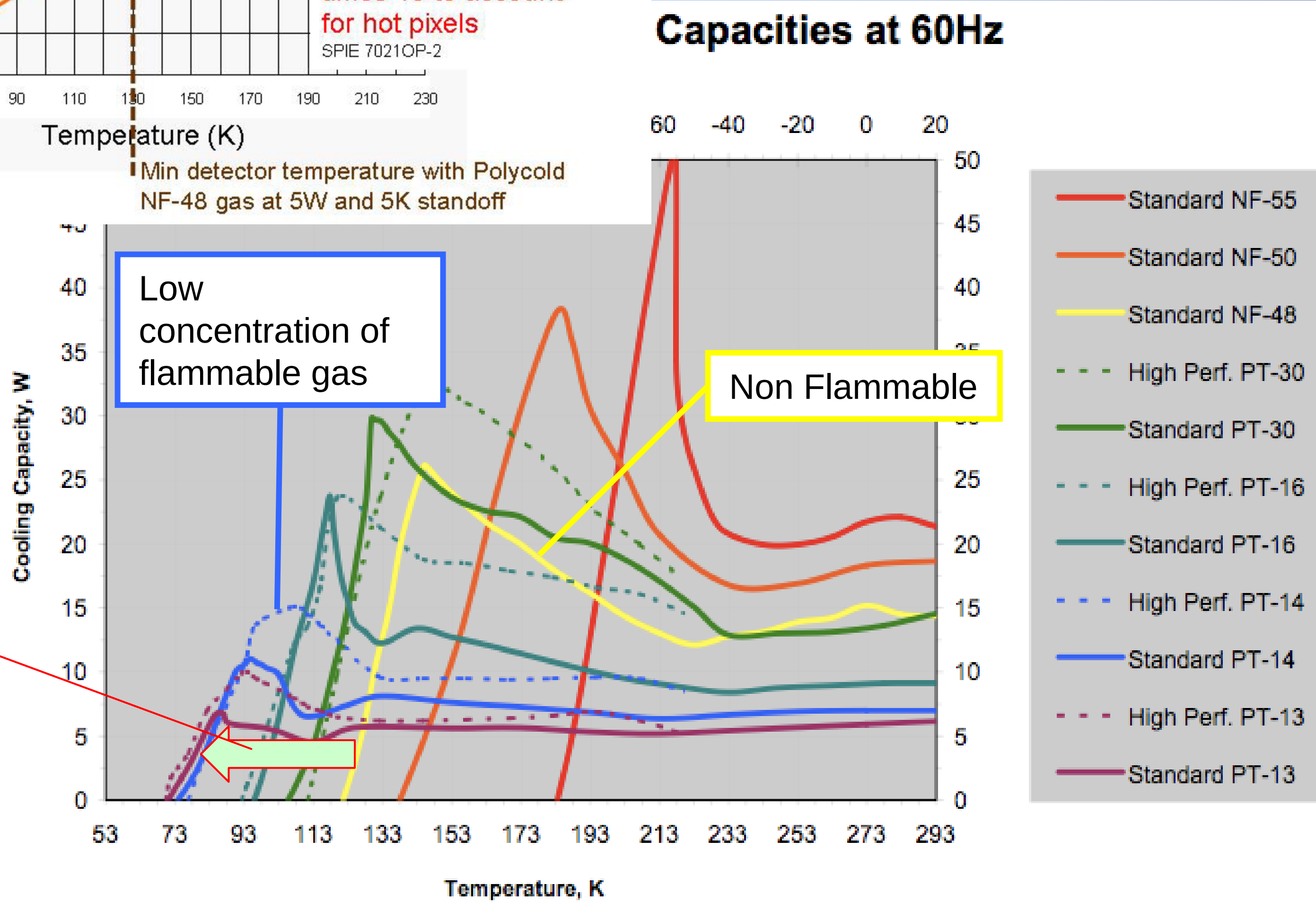
THERMAL LOAD & COOLING TIME

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 m2 radiation shield : < 2 W
  - 0.0009 m2 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



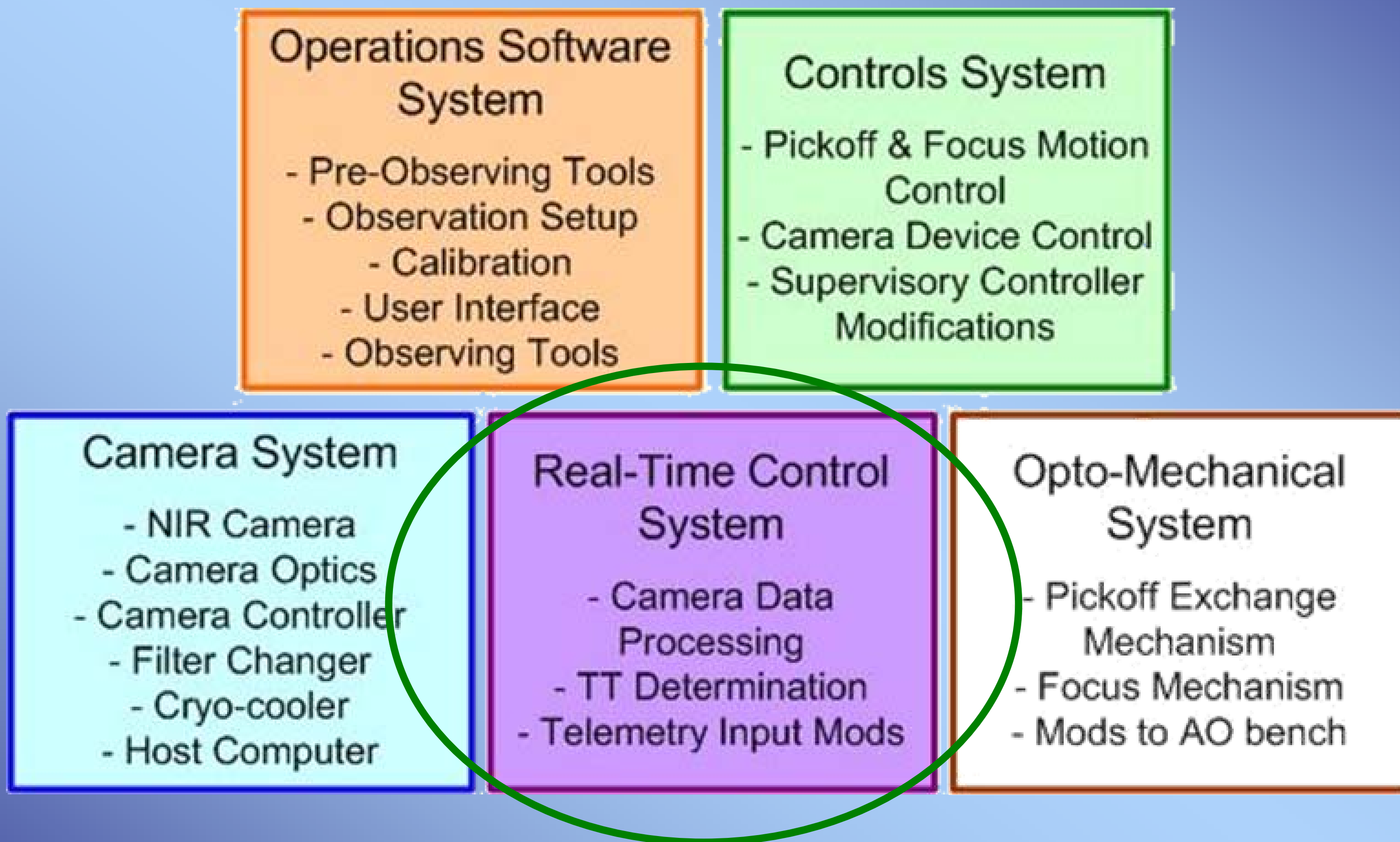


Lower temperature suppresses hot pixels that appear at the high detector bias desired to reduce noise

Real-Time Control System Design

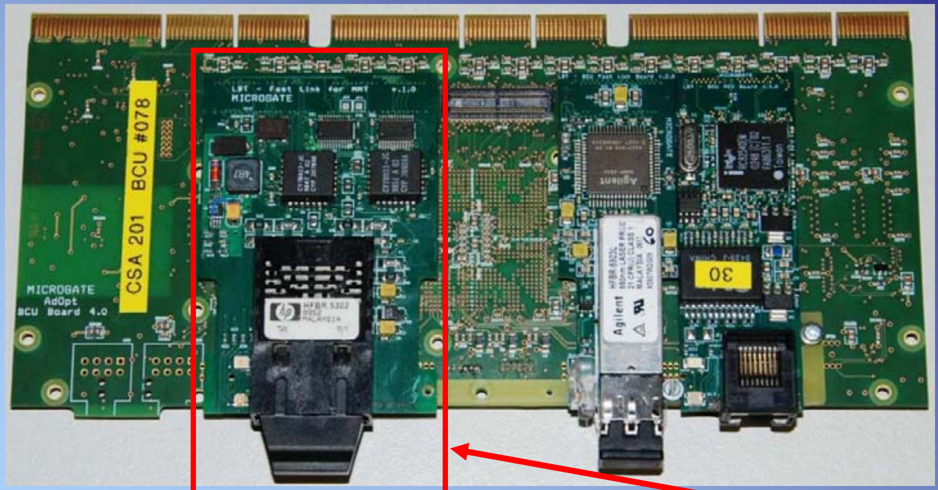
Roberto Biasi
Microgate

Design Overview - Subsystems

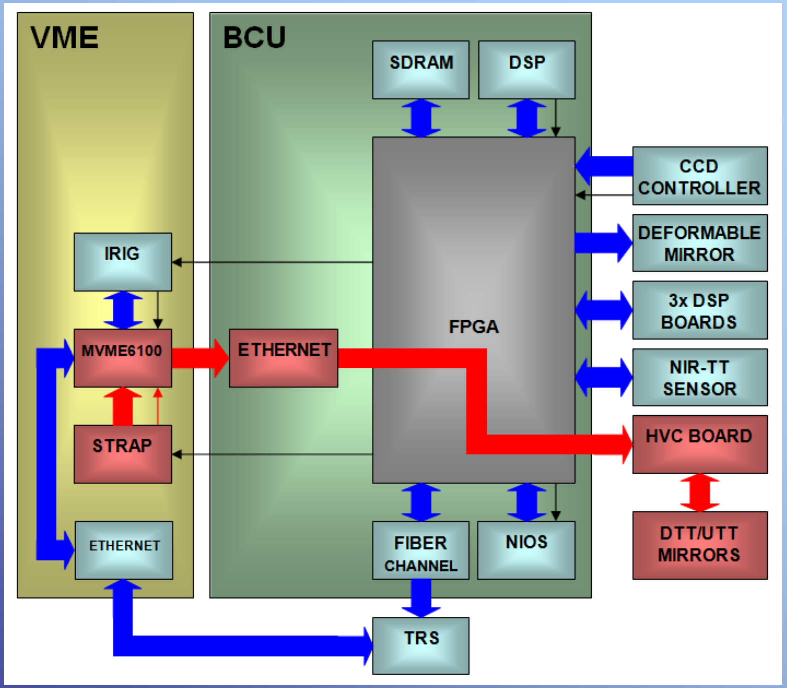


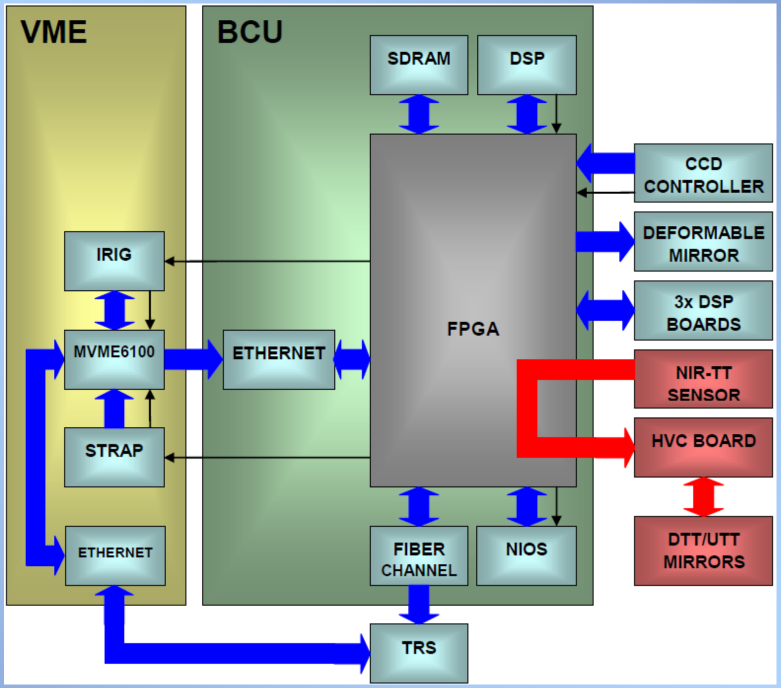
RTC Design

- 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



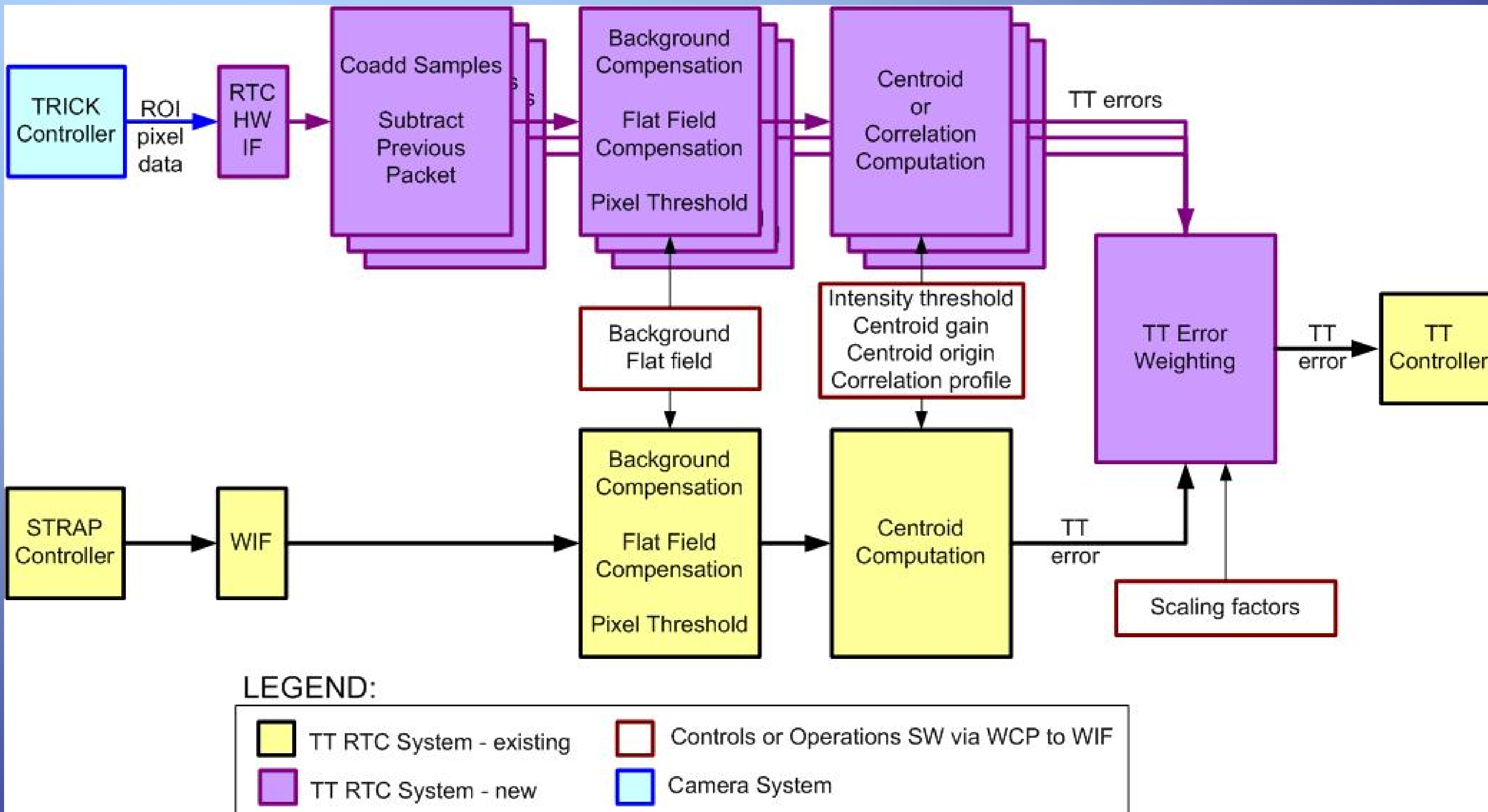


RTC – STRAP & NIR-TT

- STRAP and NIR-TT can work simultaneously
- Final TT command determined by a ‘merging’ vector containing the weights to be applied to the STRAP output slopes and to the NIR-TT ROIs outputs (up to 8 ROIs)
- Synchronism: both modes supported
  - STRAP synchronous, NIR-TT asynchronous (*slave*)
  - STRAP asynchronous, NIR-TT synchronous (*master*)

Mode	**DTT Mirror**	**UTT Mirror**
NGS	Used, driven by WFP	Not used
LGS	Used, driven by STRAP and/or NIR-TT	Used, driven by WFP
Dual NGS	Used, driven by STRAP and/or NIR-TT	Used, driven by WFP

RTC – Control Loop



RTC – Performance

Specification: max 0.5ms latency – up to 2kHz maximum loop rate

Correlation algorithm latency summary (all included)

Sub-aperture size (NxN)	Cycles for direct computation	Time for direct computation (including transfer and contingency) [µs]	Cycles for FFT computation (estimated)	Time for FFT computation (estimated, including transfer and contingency) [µs]
2x2 x8 (ROIs)	80	101	144	102
4x4 x8 (ROIs)	1088	105	1120	105
8x8 x8 (ROIs)	17424	196	6768	140
16x16 x2 (ROI)	69652	481	12016	172

'Classic' centroiding requires negligible computational load

Telemetry - TRS

column name	postgresql datatype	system datatype
Buffertype	smallint	int16
Recordlength	smallint	int16
Timestamp	bigint	uint64
Framecounter	integer	int
nirttcoadded	bytea	array of uint16

NIR-TT Decimated Frame telemetry Buffer

column name	postgresql datatype	system datatype
Timestamp	bigint	uint64
Framecounter	integer	Int
conf_id	integer	Int
nirttroislopes	bytea	array of float
nirttroifocus	bytea	array of float
Dttcentroids	bytea	array of float
Dttcommands	bytea	array of float
Dttstraingage	bytea	array of float
dttcommandsclipped	bytea	array of float

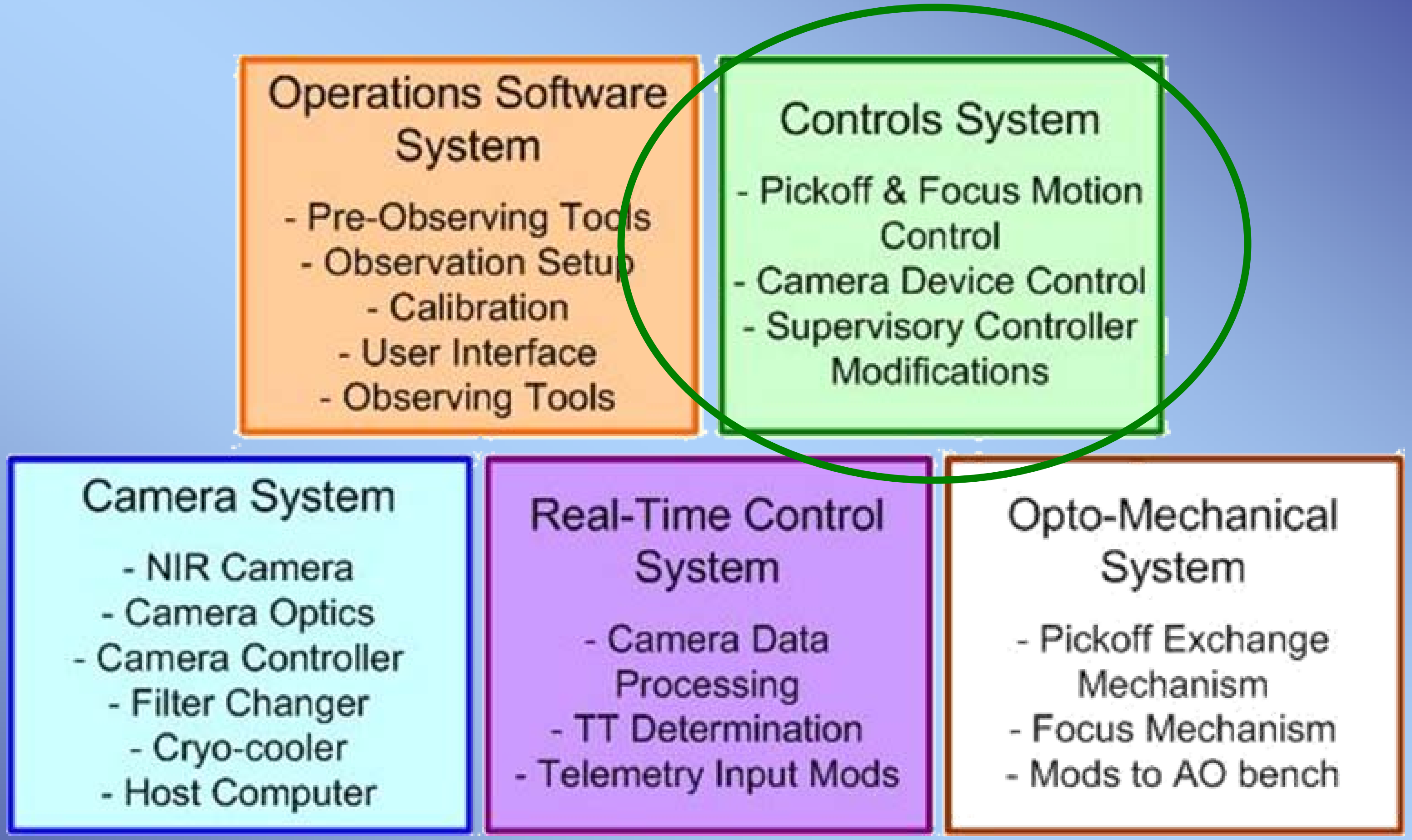
NIR-TT Full Frame telemetry Buffer

- Raw NIR-TT sensor pixel data NOT included in DFB (bandwidth + data handling limit)
- Required by SOW, section 8.2
- To be addressed before DDR

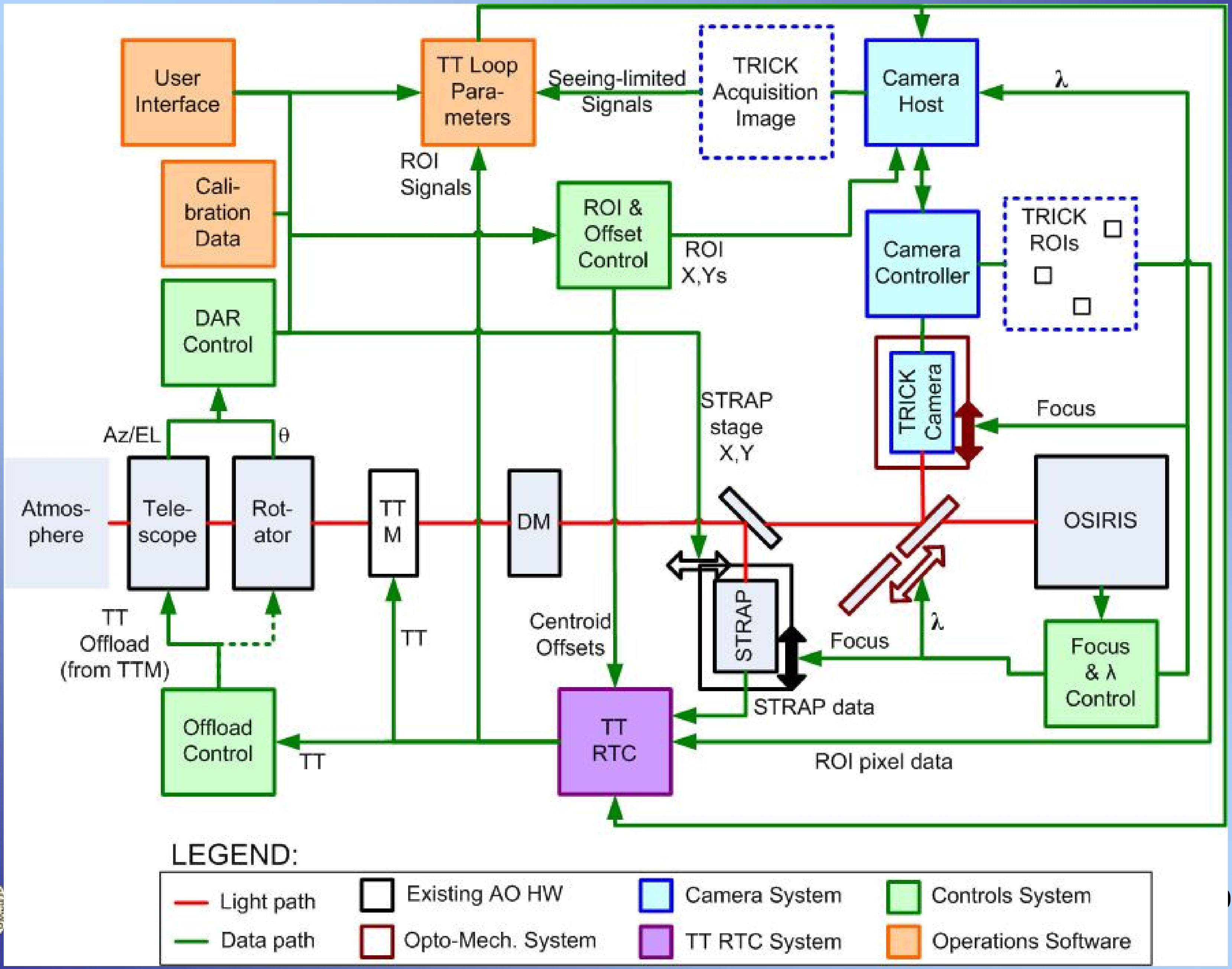
Controls System Design

Peter Wizinowich
WMKO

Design Overview - Subsystems



Controls

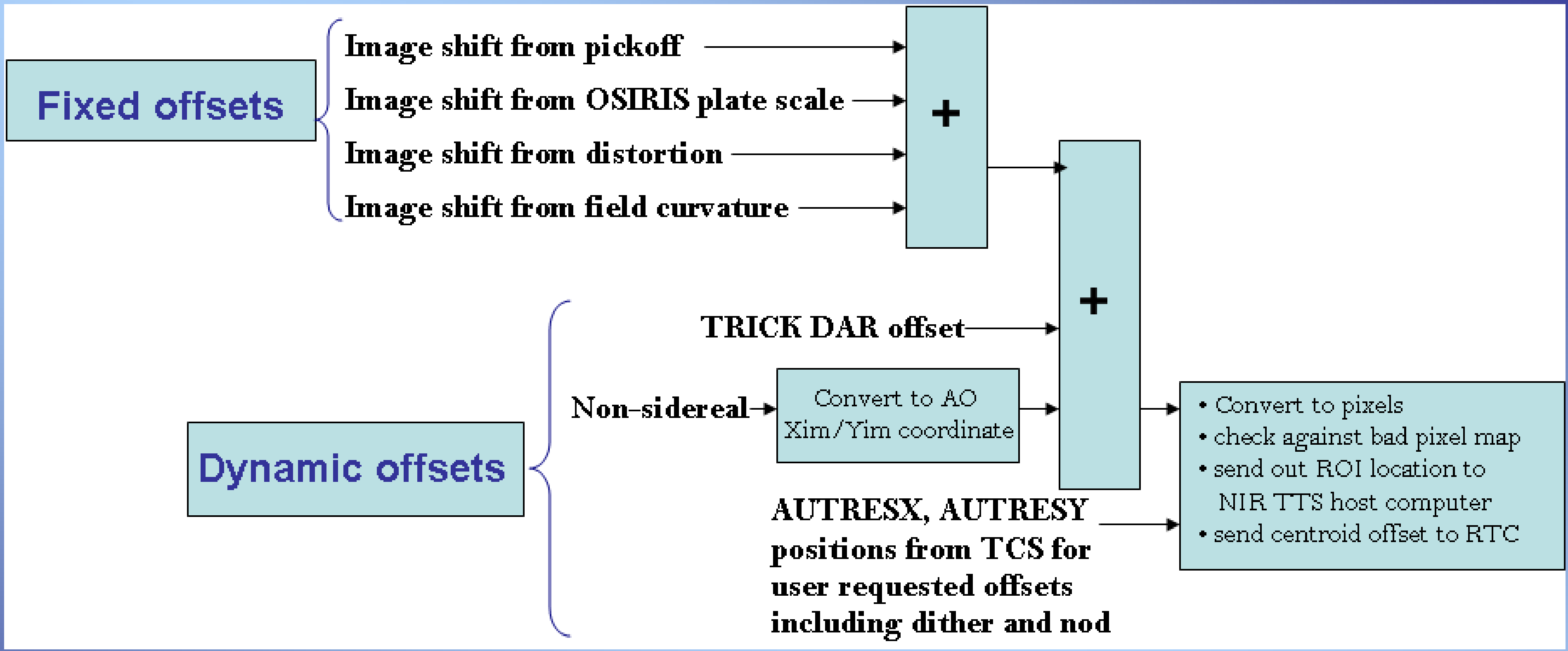


User Interface
TT Loop Para- meters
Seeing-limited Signals
TRICK Acquisition Image
Camera Host
λ
Cali- bration Data
ROI Signals
ROI & Offset Control
ROI X,Ys
Camera Controller
TRICK ROIs
DAR Control
STRAP stage X,Y
TRICK Camera
Focus
Az/EL
θ
Atmos- phere
Tele- scope
Rot- ator
TT M
DM
OSIRIS
TT Offload (from TTM)
TT
Centroid Offsets
STRAP
Focus
λ
Focus & λ Control
STRAP data
Offload Control
TT
TT RTC
ROI pixel data
LEGEND:
Light path
Data path
Existing AO HW
Opto-Mech. System
Camera System
TT RTC System
Controls 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



- 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 OOCD
  - 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 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
- Internal 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
- External Camera Optics
- Focus Mechanism

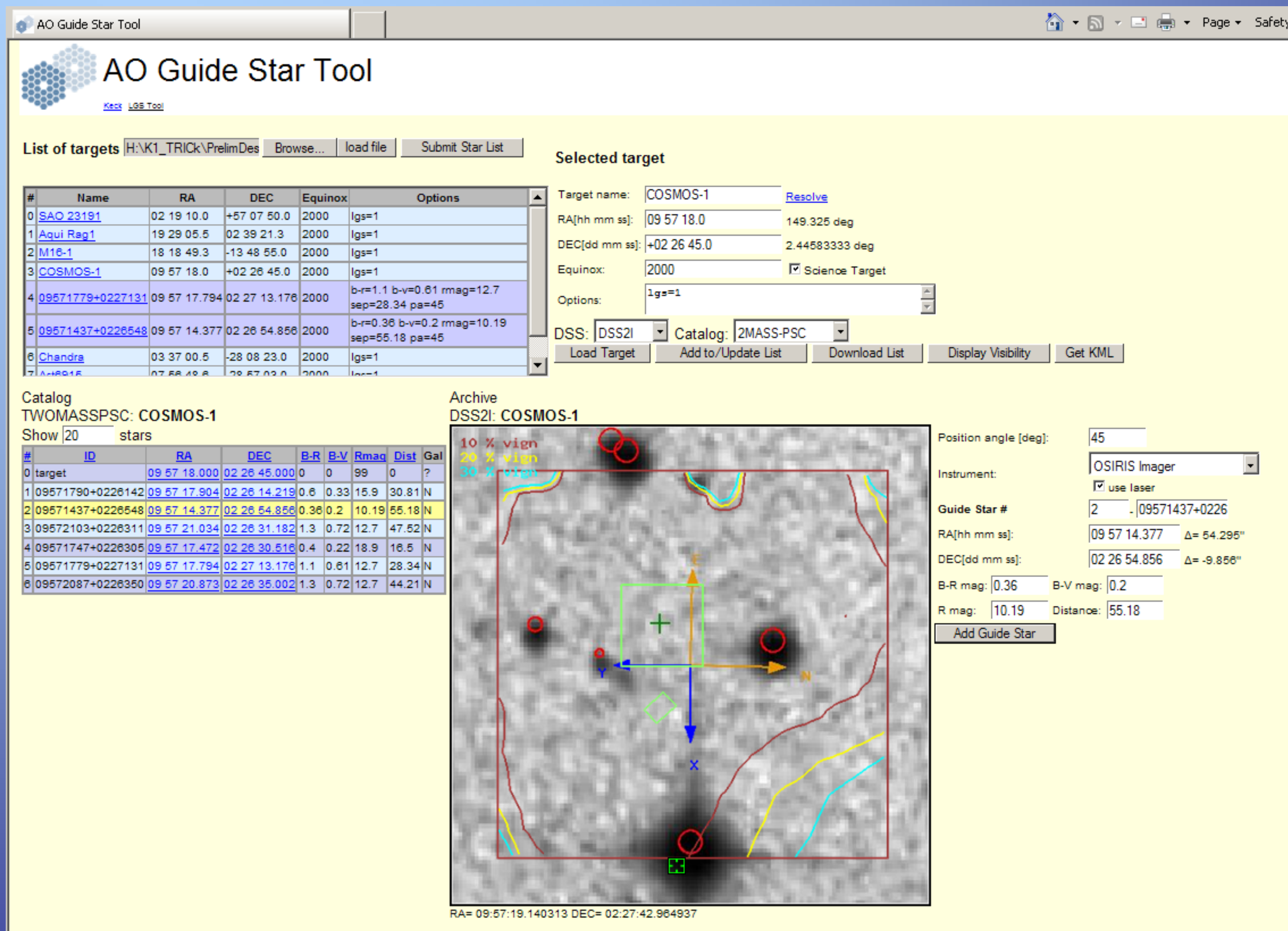
Operations Software

- 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

Operations Software Tools

Modify current guide star selection tool

NIR star catalogs, starlist format, & display OSIRIS FoV



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?

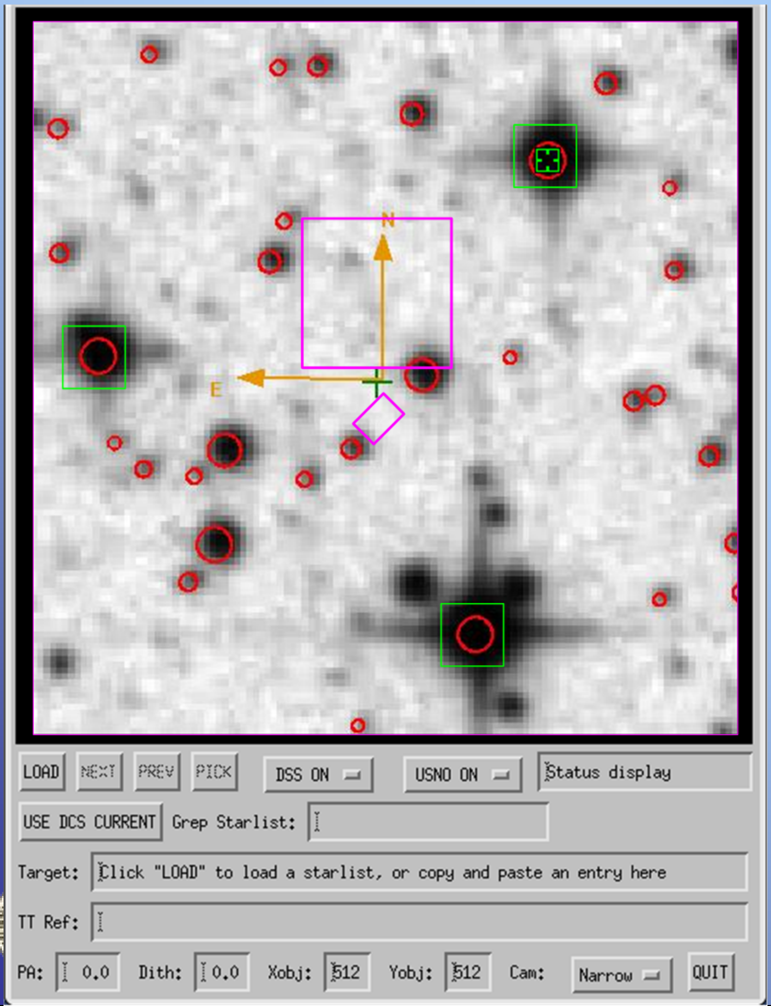
Response:

- Sorry for confusion on this topic
  - due to incomplete updates of the OOCD & 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

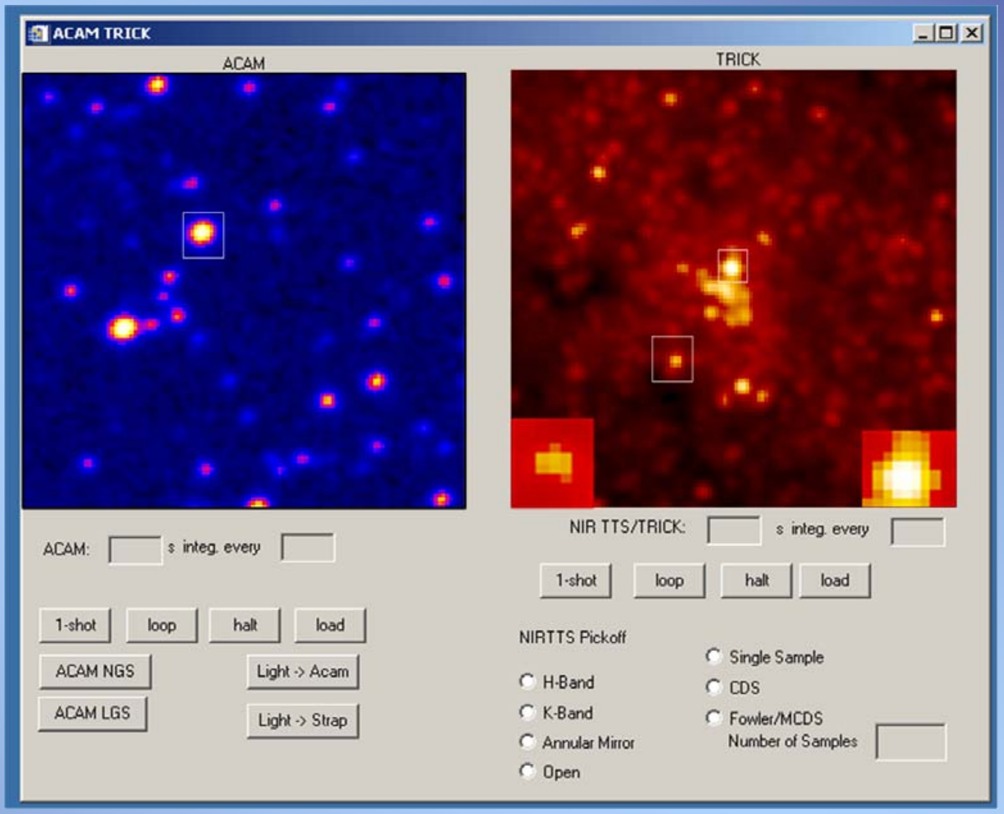
TTS/NIR planning widget

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



ACAM & TRICK (full frame)

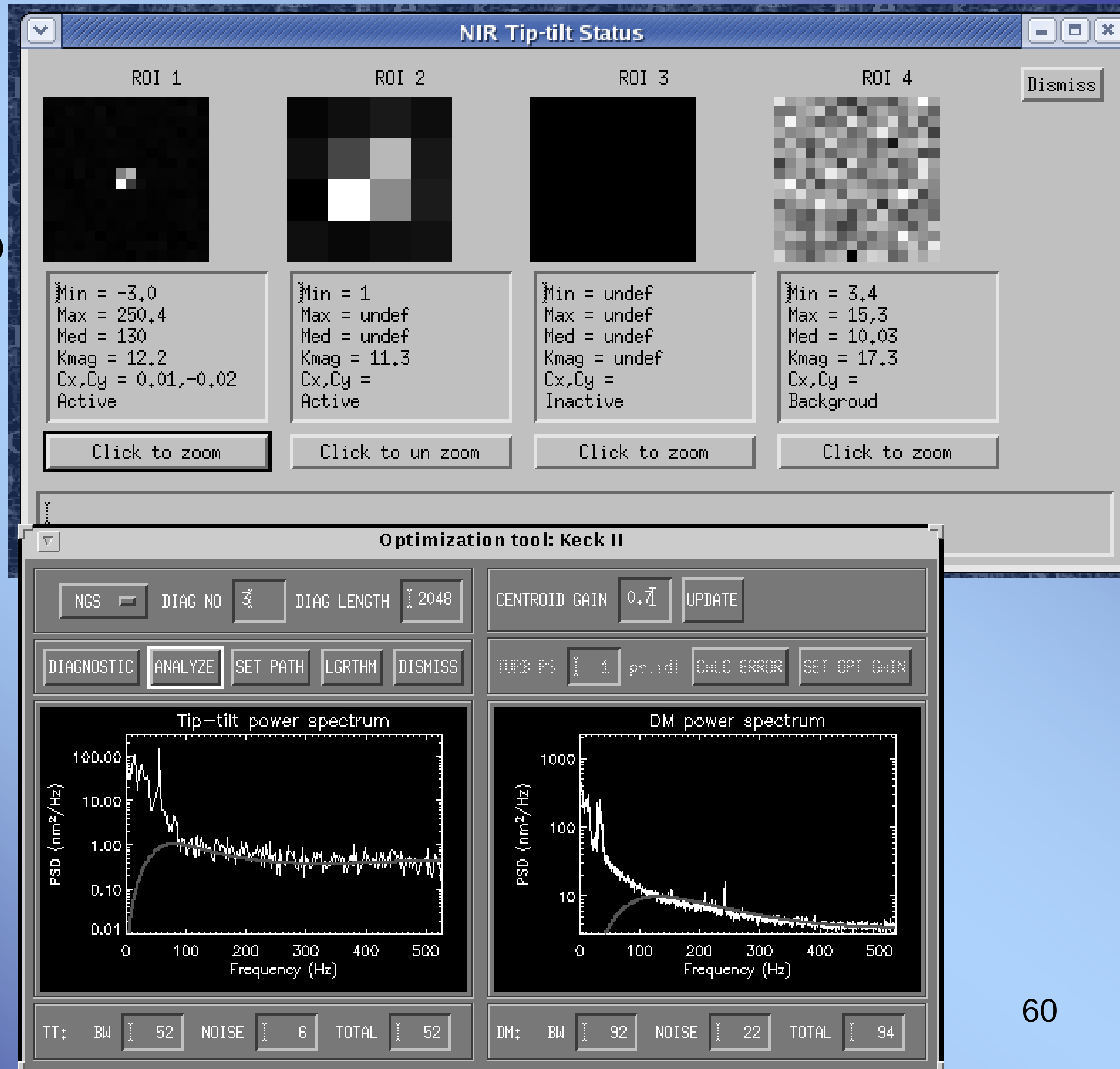
Course acquisition & field ID



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)

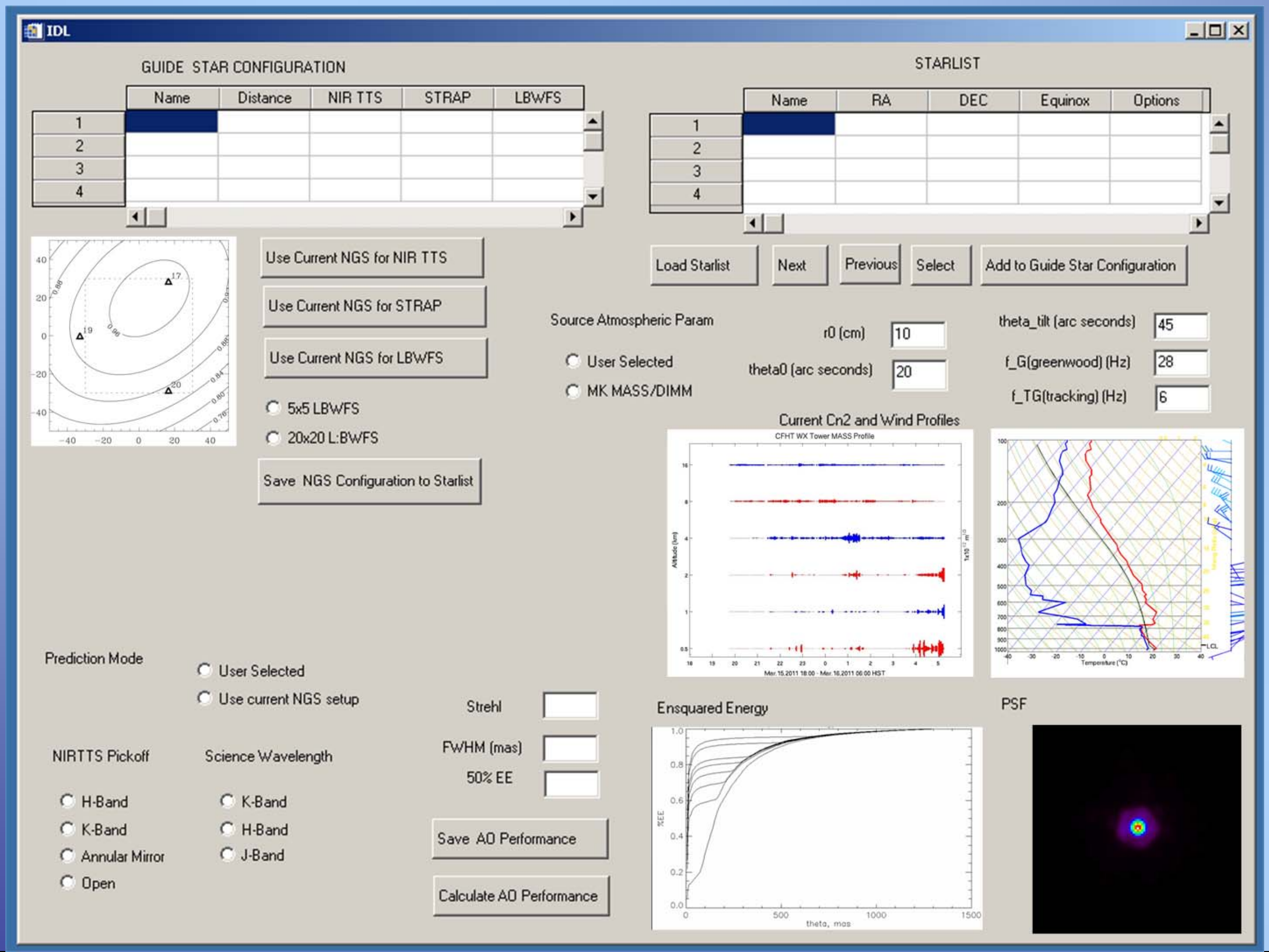
  3) Use direct estimation of image "size" from seeing disk and Strehl estimates (PDM sections 8.5.4 & 8.5.5)

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



Acceptance, Integration & Test

Peter Wizinowich
WMKO

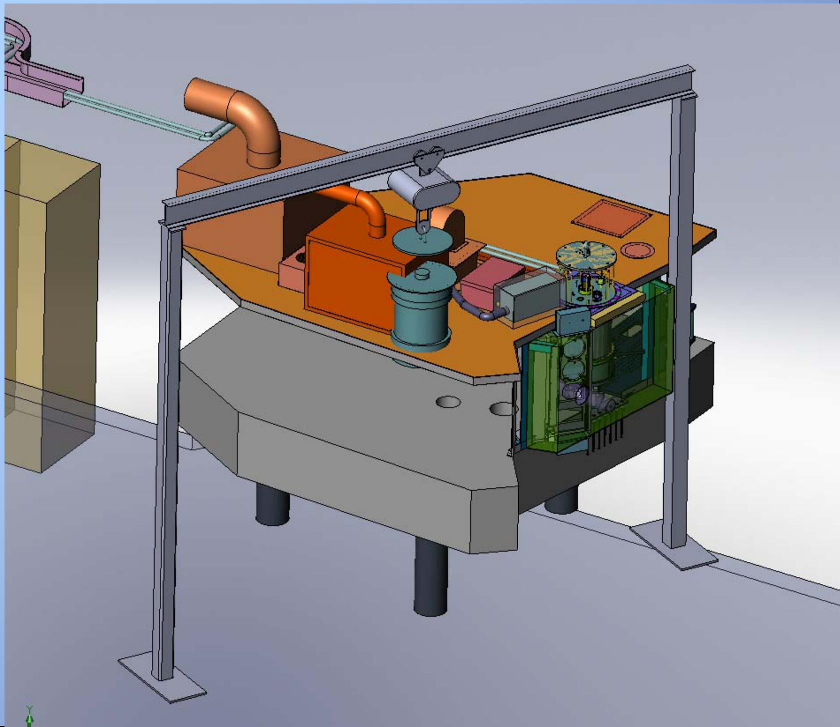
Acceptance

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

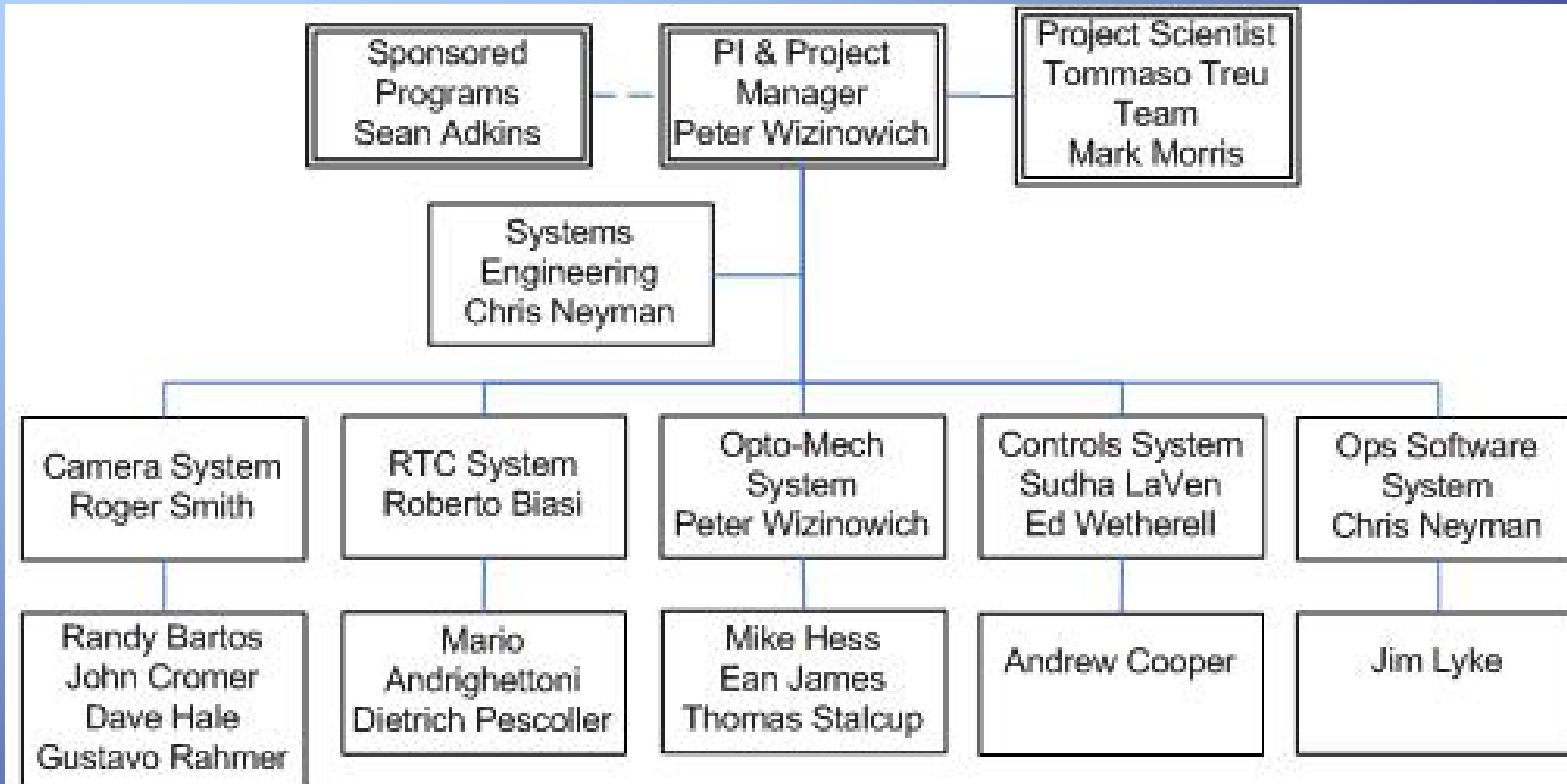
- Bench mods to be performed before OSIRIS move in late Dec/11
- RTC installation & test
  - Install alongside existing RTC & verify same performance 1st
- Opto-mechanical & camera installation & test
- Controls software installation & test
- Operations software installation & test
- Interface testing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

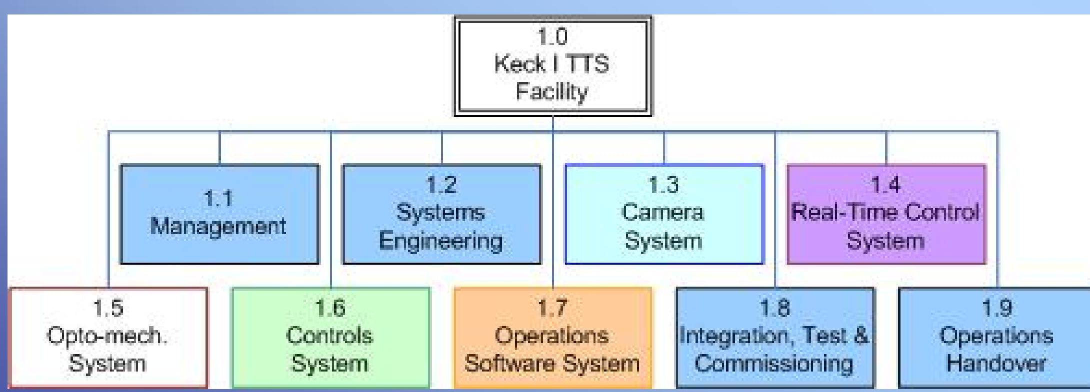


Project Management

Peter Wizinowich
WMKO

Project Organization





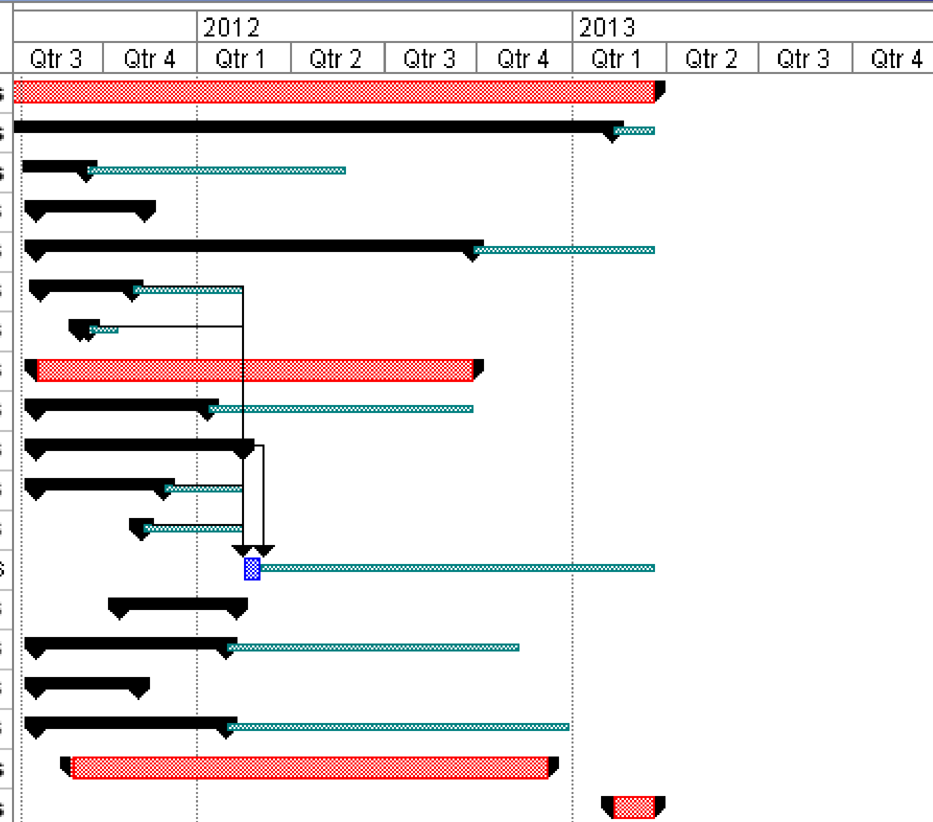
Project Milestones

Milestone	Date in Proposal	Date in Current Plan
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

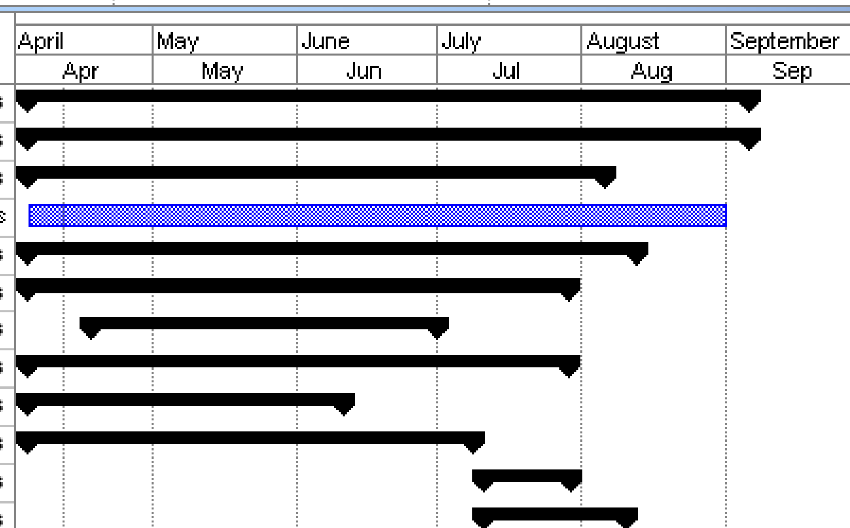
Camera

ID	WBS	Task Name	Work
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 Commisioning Support**	**308 hrs**



DD

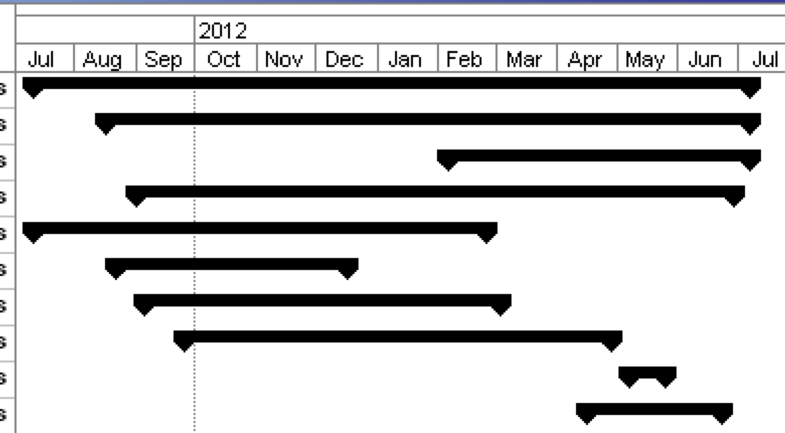
ID	WBS	Task Name	Work
1	**1**	**NIR TTS Detailed Design**	**1,525 hrs**
2	**1.1**	**Project Management**	**355 hrs**
11	**1.2**	**Systems Engineering**	**160 hrs**
23	1.3	Camera System	0 hrs
24	**1.4**	**Real-Time Control System Design**	**22 hrs**
27	**1.5**	**Opto-mechanical System**	**428 hrs**
28	**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

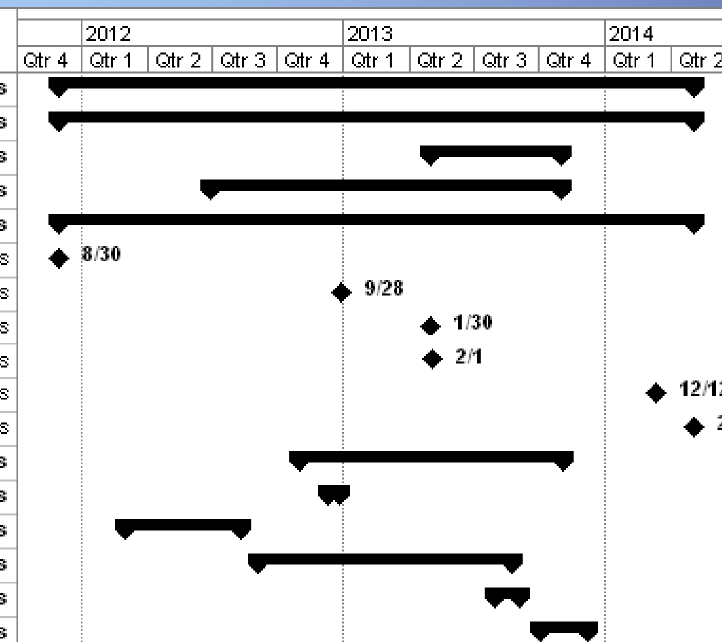
FSD

ID	WBS	Task Name	Work
1	1	**Keck I TT Facility**	2,483 hrs
2	1.1	**Project Management**	256 hrs
12	1.2	**Systems Engineering**	110 hrs
23	1.3	**Camera System**	120 hrs
26	1.4	**Real-time Control**	152 hrs
31	1.5	**Opto-mechanics**	326 hrs
43	1.6	**Controls**	510 hrs
51	1.7	**Operations Software**	933 hrs
68	1.8	**Integration, Test & Commissioning**	32 hrs
70	1.9	**Operations Handover**	44 hrs



DC

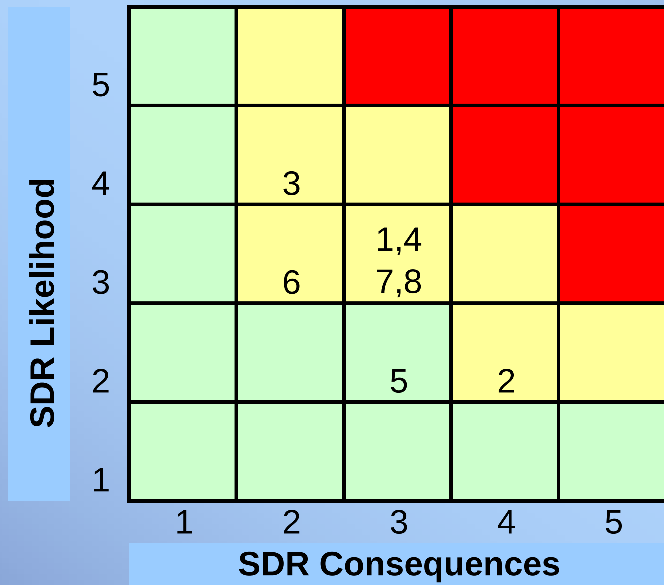
ID	WBS	Task Name	Work
1	1	Keck I TT Facility	2,242 hrs
2	1.1	Project Management	142 hrs
3	1.1.1	Planning & Tracking	32 hrs
6	1.1.2	Meetings	110 hrs
9	1.1.3	Milestones & Design Reviews	0 hrs
10	1.1.3.1	Detailed Design Review	0 hrs
11	1.1.3.2	TTF Sensor Pre-Ship Review	0 hrs
12	1.1.3.3	Pre-Summit Review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

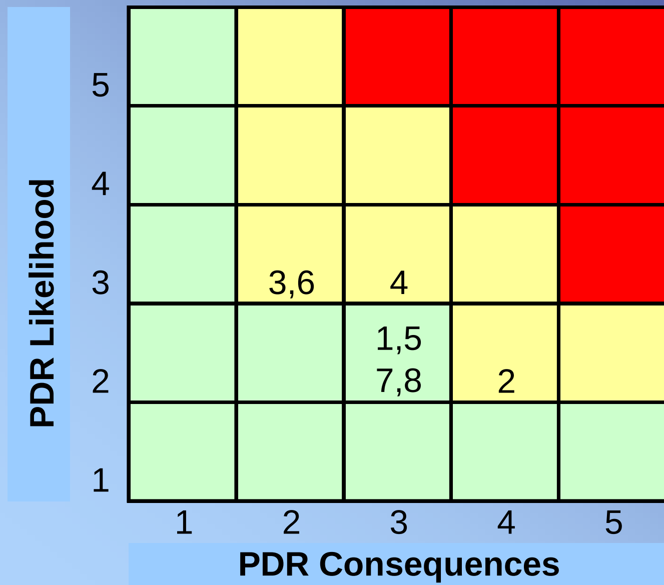


Project Budget

Expenses	Title	Person Months	Notes	Year One ACTUAL 8/1/10 9/30/10	Year Two Thru SDR 10/01/10 11/30/10	Thru PDR 12/01/10 4/10/11	4/11/11 9/30/11	Year Three 10/01/11 09/30/12	Year Four 10/01/12 09/30/13	Total Revised Budget
A. Senior Personnel	**Title**									
P. Wizinowich	Principal Investigat	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
(2) Total Senior Personnel		18	1	**$ 4,909**	**$ 15,289**	**$ 30,690**	**$ 23,251**	**$ 19,311**	**$ 6,866**	**$ 100,316**
B. Other Personnel										
(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				$ -						$ -
Total Salaries and Wages				**$ 9,831**	**$ 23,510**	**$ 91,736**	**$ 73,758**	**$ 149,206**	**$ 117,565**	**$ 465,606**
C. Fringe Benefits			2	$ 2,320	$ 6,066	$ 23,668	$ 19,029	$ 38,048	$ 29,943	$ 119,073
Total Salaries, Wages and Fringe Benefits				**$ 12,151**	**$ 29,576**	**$ 115,404**	**$ 92,787**	**$ 187,254**	**$ 147,508**	**$ 584,679**
D. Equipment										
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
Total Equipment				**$ -**	**$ 256,000**	**$ 23,950**	**$ 10,170**	**$ 96,880**	**$ -**	**$ 387,000**
E. Travel										
Domestic			3	$ -		$ 315	$ -	$ 4,400	$ -	$ 4,715
Foreign				$ -			$ -	$ -	$ -	$ -
F. Other Supplies				$ -			$ -	$ -	$ -	$ -
G. Other Direct Costs										
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				$ -			$ -	$ -	$ -	$ -
Total Other Direct Costs				**$ 331**	**$ 44**	**$ 121,835**	**$ 131,555**	**$ 362,626**	**$ 500**	**$ 616,890**
H. Total Direct Costs				**$ 12,482**	**$ 285,620**	**$ 261,503**	**$ 234,512**	**$ 651,159**	**$ 148,008**	**$ 1,593,285**
I. Indirect Costs (F&A)										
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
Total Indirect Costs				**$ 6,865**	**$ 19,891**	**$ 67,431**	**$ 90,096**	**$ 42,191**	**$ 70,286**	**$ 296,759**
J. Total Direct and Indirect Costs				**$ 19,347**	**$ 305,511**	**$ 328,934**	**$ 324,607**	**$ 693,351**	**$ 218,294**	**$ 1,890,044**
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.