



HETDEX Control System Workshop



HETDEX Control System Workshop

Thursday, March 5
Friday, March 6

THR/MEC

Workshop Goals

- Communicate current control system issues
- Identify new ones
- Communicate SW team's understanding of issues
- Resolve and document as many issues as possible
- Develop plan for issues that cannot be resolved during workshop
 - e.g. define smaller working groups
- Plan follow-up actions

- Results will be integrated into requirements documents
 - e.g. Tracker and Software documents

Agenda

Day 1 – Thursday, Mar 5, 2009

1:00 - 5:00 - Workshop Session 1

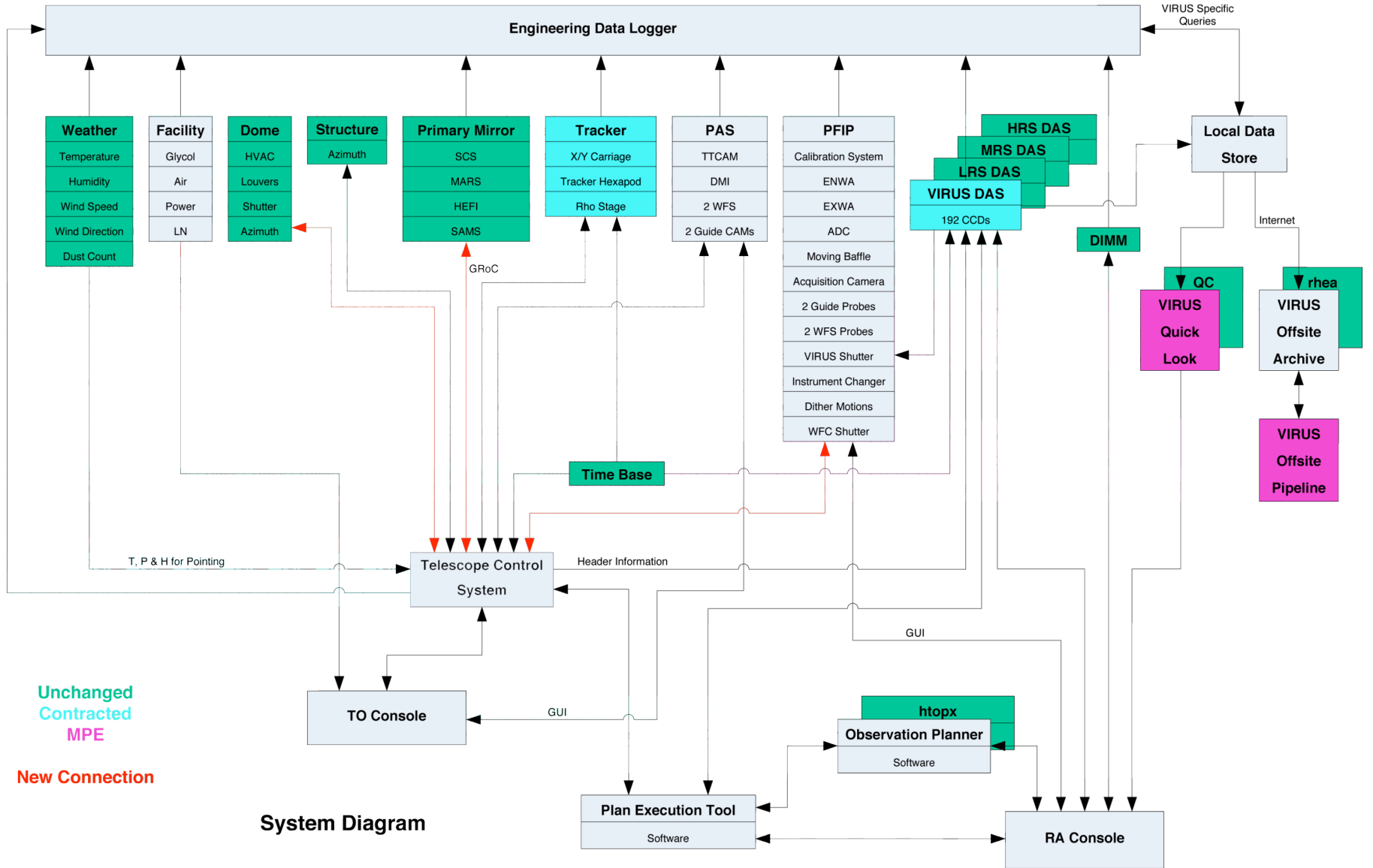
Topic	Duration	Start Time
1 Intro	5	1:00 PM
2 Tracker use cases	90	1:05 PM
3 Tracker software interface	15	2:35 PM
Break	10	2:50 PM
4 dSPACE / ControlDesk / TCS Architecture	30	3:00 PM
5 TCS functionality - Lab Use vs HET	20	3:30 PM
6 User interface	25	3:50 PM
7 New operations procedures	45	4:15 PM

Day 2 – Friday, Mar 6, 2009

8:30 - 12:00 - Workshop Session 2

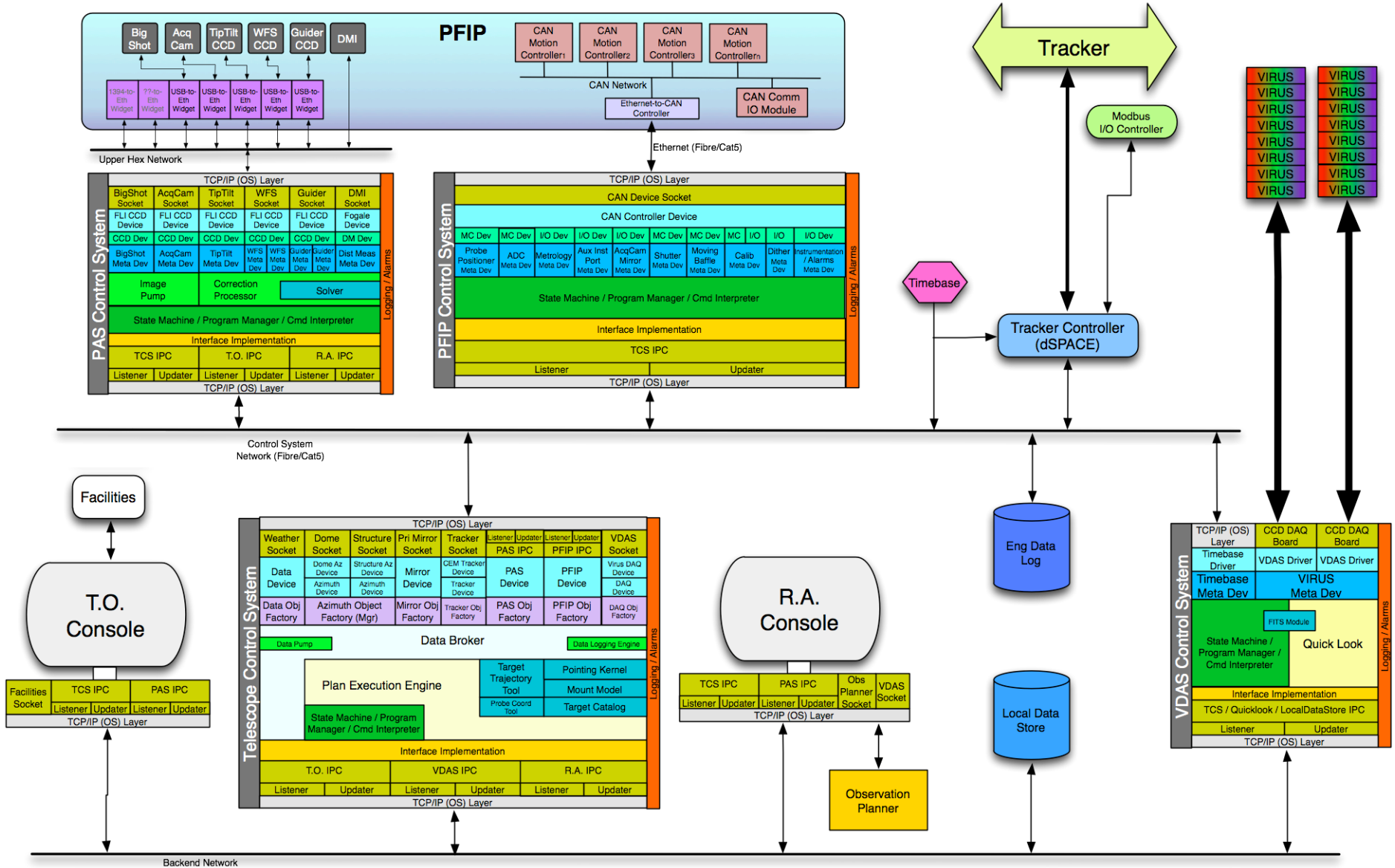
Topic	Duration	Start Time
9 Metrology and guide correction issues	50	8:30 AM
10 Should we change the way we handle focus?	15	9:20 AM
11 Tracker rotation point versus SIRP	10	9:35 AM
12 PFIP issues	15	9:45 AM
Break	10	10:00 AM
13 Mount model issues	40	10:10 AM
14 Pre-deployment testing	40	10:50 AM
15 Post-install testing	15	11:30 AM
Wrap up	15	11:45 AM

System Overview



System Diagram

Software System Architecture



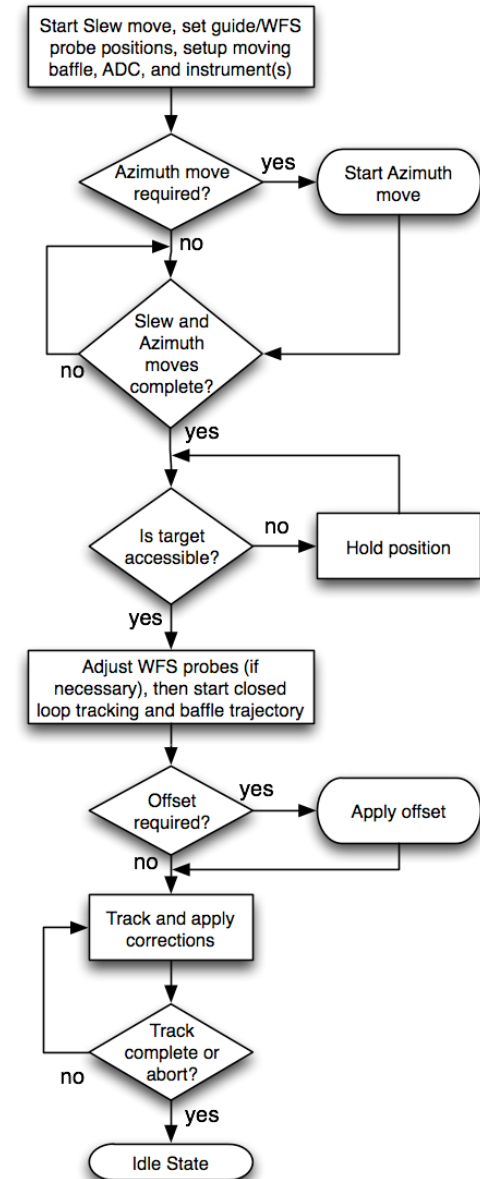
Tracker Use Cases - Overview

1. Slew to a starting point, then track a science target, sidereal
2. Slew to a starting point, then track a science target, non-sidereal
3. “Move” (slew or track or slew-then-track) to some coordinates and hold
4. “Move” (slew or track or slew-then-track) to some coordinates and shut down all motors
5. Piston the mirror with DmiDaq
6. Make a series of trajectories or pointings to map out mount model terms
7. Use the hardware hand paddle
8. Operate with (some) safeties disabled

Want to define an “official” set of use cases to drive development details

Tracker Use Cases - # 1

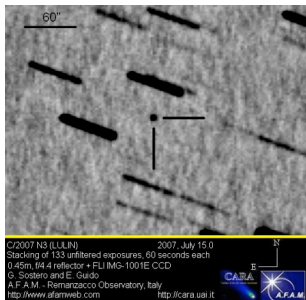
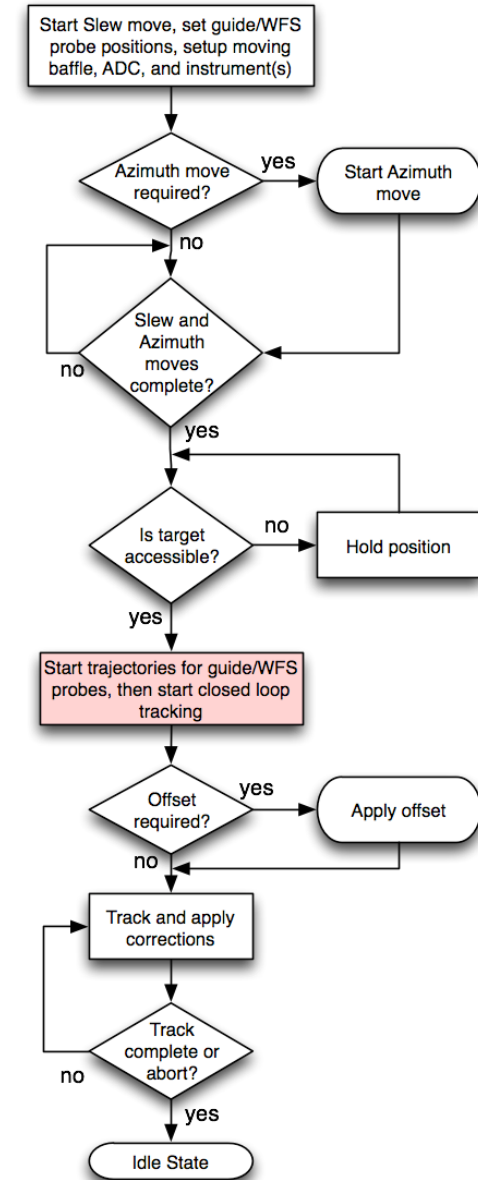
1. Slew to a starting point, then track a science target, sidereal
 - Variants include fixed azimuth and making an azimuth move (requiring a trajectory recalculation)
 - May have to apply an offset along the sphere once in closed-loop tracking mode, for acquisition or blind offset
 - When asked to set up on a target not yet in the accessible box, what to do?
 1. Could delay any motion until the necessary start time
 - ➔ 2. Or could slew to edge of box and hold
 - Starting track when object enters box (Jim prefers this approach, since failures occur most often at start of motion)
 - TCS will compute fixed positions for guide/WFS probes; will we peak up WFS probes?
 - TCS will compute trajectory for moving baffle
 - Possibly implemented as a series of discrete move requests, although a trajectory may be just as easy or easier, depending on details
 - The ADC causes an offset to the target position
 - Along the sphere?



Tracker Use Cases - # 2

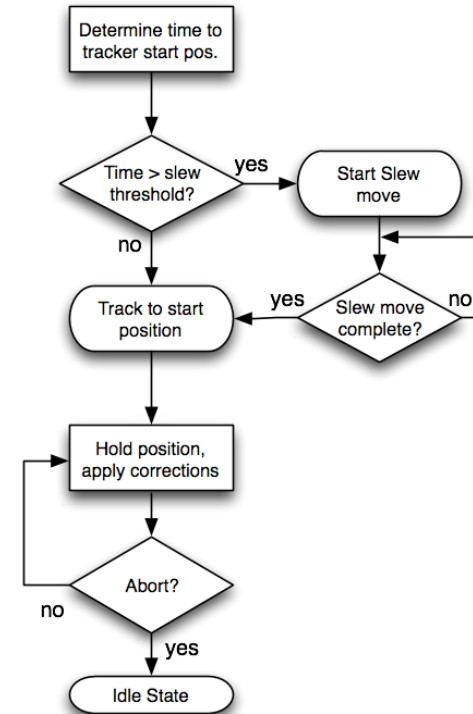
2. Slew to a starting point, then track a science target, non-sidereal

- Need to extend current trajectory code for moving targets
 - Affects the “best azimuth” calculation as well
- TCS will need to compute *trajectories* for guide/WFS probes
 - Need to work out details for the required coordinated motion
 - Need a scheme for registering probes and calibrating probe motion over the FOV
- There are significant limitations on track time for closed loop operation with full metrology
 - But not for open loop operation
 - Or partial metrology using just TTCAM, DMI
 - Would that be accurate enough to be of scientific interest?



Tracker Use Cases - # 3

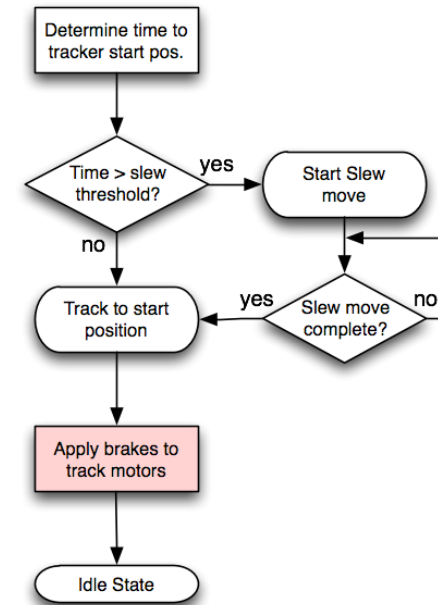
3. “Move” (slew or track or slew-then-track) to some coordinates and hold (i.e., closed loop holding)
 - Slew move if speed is priority, track if accuracy is priority, slew/track if both
 - Presumably shutting down slew motors and holding with track motors
 - Possibly accepting corrections
 - Either manual input, or from metrology
 - This is a change from the behavior of the current tracker where a trajectory must be running first
 - Variants: on-sphere (metrology available) or off
 - How relevant is metrology if we are not moving?
 - How close to sphere for TTCAM and DMI to work?
 - How well do TTCAM, DMI work during the day?
 - Even if the mirror is not well stacked?
 - Even at night, and on sphere, guide/WFS sensors are problematic, since we are far from sidereal rate
 - Use for engineering (?) or geostationary targets
 - If we are taking “science” data, we’ll need to position baffle and ADC as well
 - Are geostationary targets really stationary?
 - Or do they have a complicated (but slow) non-sidereal trajectory? (so we are back to Use Case #2?)



Tracker Use Cases - # 4

4. “Move” (slew or track or slew-then-track) to some coordinates and shut down all motors

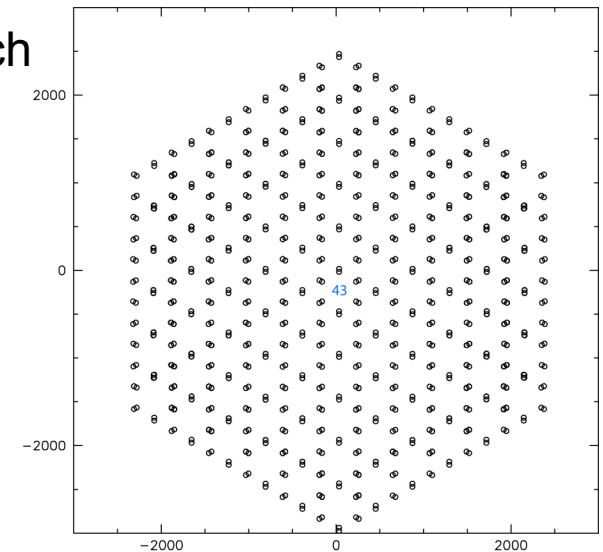
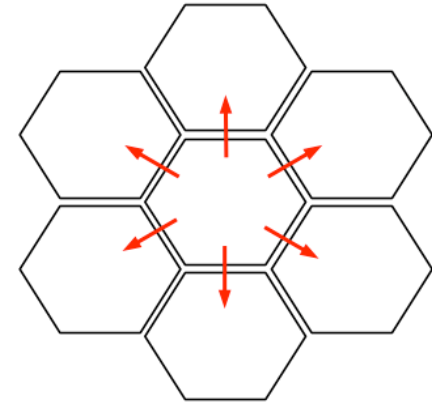
- Slew move if speed is priority, track if accuracy is priority, slew/track if both? Or is slew sufficient?
 - That is, how accurately do we need to position in this mode?
 - When you shut down, how accurate is the final resting position when the brakes are applied?
- For stacking or engineering or just stowing
- There are a few special places we often move to
- Would like to power up and move a single axis or leg at a time
- Maintenance tasks:
 - Replace tracker component or hexapod leg
 - Remove/install payload or WFC
 - Special case: Moving the tracker when it is tied down
 - To safely test a newly installed part, before taking full weight
 - Need to sort out details and sequencing
 - » Only move into strap
 - » Move a little, free up strap, move some more, etc.
 - When/how do we override the strap-out-of-storage-slot safety? Is this still the design?
- Do we need to specify an explicit speed for some moves? (Would need to add to API.)



Tracker Use Cases - # 5

5. Piston the mirror with DmiDaq

- Special short trajectories between pairs of X,Y coordinates, but on sphere
 - Implemented via a special TCS command
- Track across mirror edges, or at mirror centers (for reference)
 - Slew then track to desired point
 - Take a measurement
 - Repeat
 - Reference at beginning and end to mirror 43
- Pistoning all the mirrors the current DMI can reach takes 10 hours
- Use this mode to register the Primary Mirror (i.e., initial survey after WFC installed)?
 - What sorts of trajectories / pointings will be used?
 - How often will this be needed?
 - Or is this just part of building the mount model?
- Can make the new TCS 100% backward compatible with the existing program, if needed



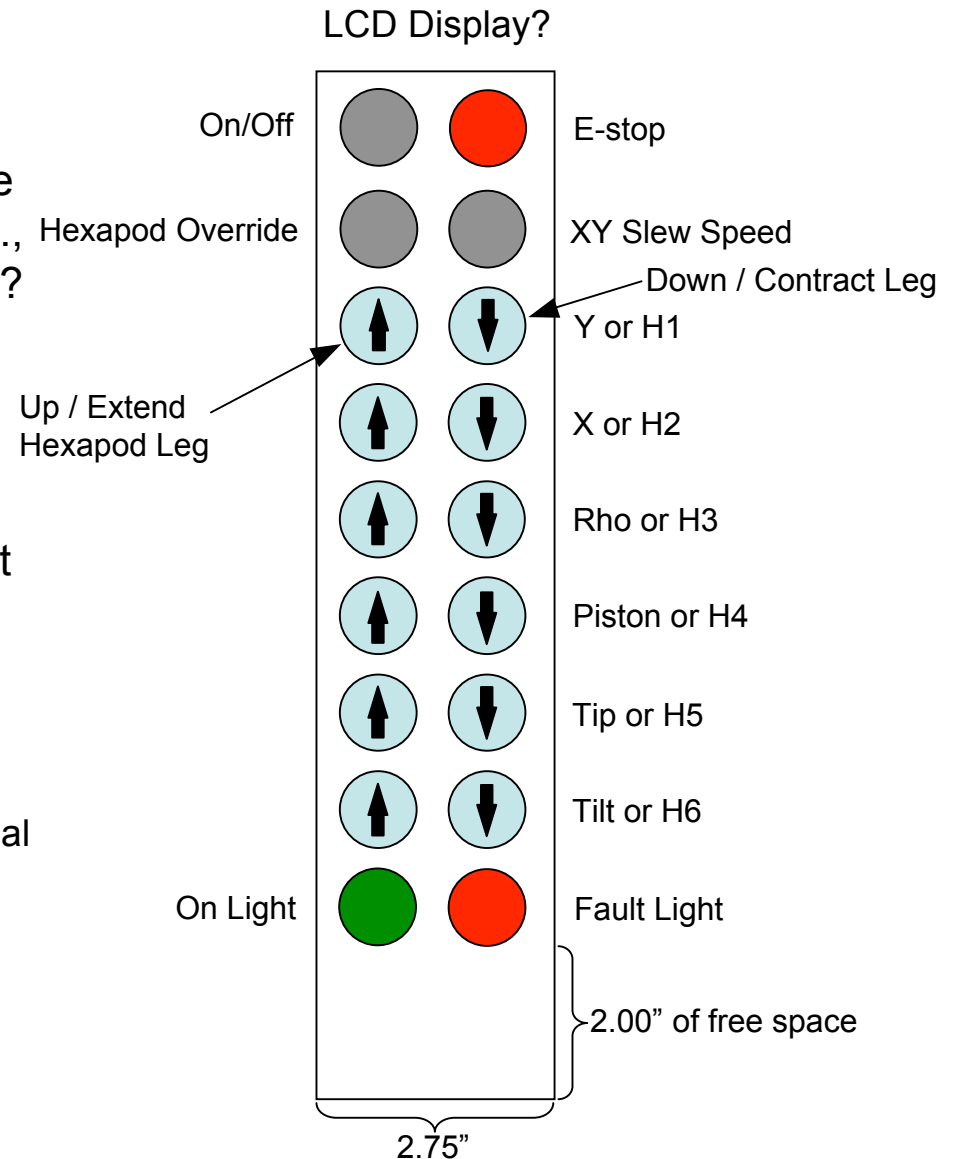
Tracker Use Cases - # 6

6. Make a series of trajectories **or pointings** to map out mount model terms (possibly during the day, or at faster than sidereal rates)
 - Run a track **or make a series of pointings**?
 - Are pointings ever used instead of trajectories?
 - What sorts of trajectories are used?
 - Always at sidereal rate or would faster be better?
 - Can we run trajectories much faster than sidereal rate? Geometry of tracks?
 - What does the grid of trajectories look like? Orientation? Spacing?
 - What measurements are being made?
 - Can compare primary and secondary metrology techniques, for instance
 - What terms are being fit for the results?
 - Presumably, all mapped points need to be on the sphere for mount model purposes
 - Could run during the day
 - But guide/WFS sensors not available, mirror may not be stacked well
 - If run much faster than sidereal rate, guide/WFS sensors not available
 - Are runs with just TTCAM, DMI useful? Does mirror need to be stacked?

Tracker Use Cases - # 7

7. Use the hardware hand paddle

- What exactly can you do with this?
- What would user like to be able to see on hand paddle while in operation, i.e., does there need to be a small display?
- Can a user access the tracker from other control points simultaneously? Read only access? Tracker at least logs paddle moves to Eng. Logger?
- If so, what is the procedure to lock out other control points?
- Two types of manual controls are required?
 - Handheld pendant with interconnect cable
 - Laptop with wireless Ethernet: any real interest?



Tracker Use Cases - # 8

8. Operate with (some) safeties disabled

e.g., Accessing the edge/corner mirrors

- What motions are required or which safeties must be disengaged?
- Need a detailed description of this process
- Is this an issue at all if we end up with 3 DMIs?
 - Yes, because we still need to move outside of normal operating range?

Other cases?

Tracker Modes

Tracker Actions, Modes, and Characteristics (11-04-08)

Item	Action	Mode ¹					Characteristics		
		General Science	DEX Survey	Mirror Stacking	Mirror Piston	Maintenance ²	On Focal Surface ³	Pointing Accuracy	Speed/Duration
1	Sidereal tracking	✓	✓				CLC		15.041067"/sec on the sky
2	Non-sidereal tracking	✓					CLC		Between 11.04"/sec and 19.05"/sec on the sky
3	Open loop pointing	✓	✓		✓		See note 4	10" pp ⁵	As quickly as possible
4	Closed loop offset	✓	✓		✓		See note 4	0.25" pp ⁶	As quickly as possible
5	Slew to new track	✓						2" pp ⁷	As quickly as possible
6	Short rewind to new track ⁸		✓					2" pp ⁷	As quickly as possible
7	Slew ⁹			✓	✓	✓		≤ 0.5 mm	User selectable ≤ maximum slewing drive speed
8	Track ¹⁰				✓	✓		≤ 0.5 mm	User selectable ≤ maximum tracking drive speed
9	Geostationary ¹¹	✓					CLC	30" rms	
10	Stationary ¹²			✓	✓	✓			

- 1) A checkmark (i.e. ✓) indicates that this Action is relevant to a particular mode.
- 2) All axes must be able to be controlled in maintenance mode. This includes operating the X and Y axes at both tracking and slewing speeds.
- 3) "CLC" indicates that all axes are moving under Closed Loop Control in a coordinated manner to follow a celestial object.
- 4) For this action the tracker starting and stopping positions are on the focal surface. However, when moving between the start and stop positions the tracker is taking the path which requires the least amount of time to traverse. Note that this path is not required to be on the focal surface.
- 5) As per TRD 2.7.1: Pointing accuracy (open loop) to any accessible new field shall be to within 30" peak-to-peak, including changes in azimuth. As a goal this will be improved to at least 10" peak-to-peak.
- 6) As per TRD 2.7.3: The closed loop offset pointing accuracy within a 3' diameter field will be 0.25" peak-to-peak with a goal of 0.1" peak-to-peak. It will be possible to blind offset from a fiducial star to an invisible object under closed-loop control to these accuracies.
- 7) As per TRD 2.7.2: For observations where the azimuth is fixed and a small rewind of the tracker (< 1 m) is required to set on a new field – as is the case for HETDEX – the pointing accuracy (open loop) shall be 2" rms so as to guarantee rapid (and automatic) setup using metrology systems.
- 8) "Short rewind to new track" is defined as per TRD 2.8.3: For HETDEX, the requirement at fixed azimuth, is that the tracker shall be capable of slewing to the next target field, settling to the specified tracking stability, and acquiring lock on-sky within 80 seconds of shutter close from the last observation, over a 700 mm rewind distance. This period shall include acceleration/deceleration ramps and time for the tracker metrology system to re-acquire nominal optical alignment with the primary mirror.
- 9) "Slew" means to use the slewing drives (at user selectable speeds) to move one or more of the axes (simultaneously). Note that the maximum slewing speed for the X and Y axes is 80 mm/sec.
- 10) "Track" means to use the tracking drives (at user selectable speeds) to move one or more of the axes (simultaneously).
- 11) "Geostationary" means that the tracker is approximately stationary (i.e. it is accepting guide corrections to compensate for wind induced motion and seeing motions) for extended periods of time (e.g. > 60 minutes).
- 12) "Stationary" means that the tracker is in some fixed position/orientation with the brakes applied.

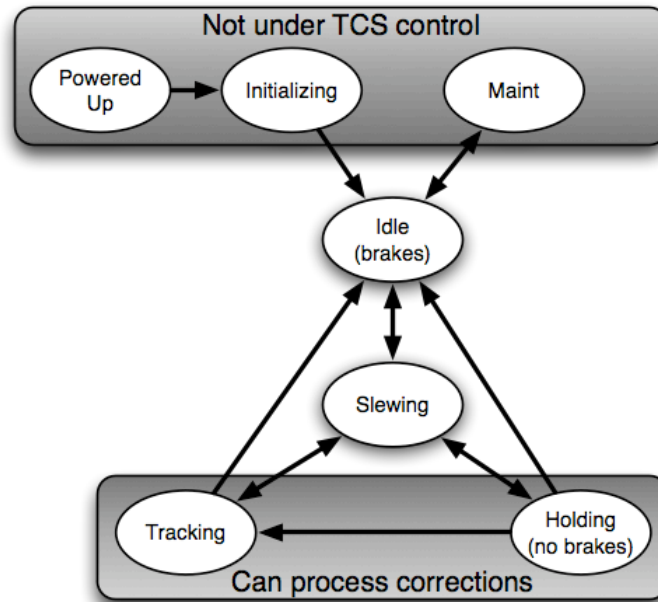
Tracker Modes

Tracker Actions, Modes, and Characteristics (11-04-08)

Item	Action	Mode ¹					Software Use Case
		General Science	DEX Survey	Mirror Stacking	Mirror Piston	Maintenance ²	
1	Sidereal tracking	✓	✓				Cases 1,6
2	Non-sidereal tracking	✓					Cases 2,6
3	Open loop pointing	✓	✓		✓		Cases 1,2,3,5,6,8
4	Closed loop offset	✓	✓		✓		Cases 1,2,3
5	Slew to new track	✓					Cases 1,2,3,6
6	Short rewind to new track ⁸		✓				Use Case 1
7	Slew ⁹			✓	✓	✓	Cases 4,5,6,7,8
8	Track ¹⁰				✓	✓	Cases 4,5,6,7,8
9	Geostationary ¹¹	✓					Use Case 3
10	Stationary ¹²			✓	✓	✓	Use Case 4

Not obvious this mapping is very instructive.

Tracker API



SET_TRAJ [time, X, Y, Z, ρ , θ , ϕ]

ABORT

COR [X, Y, Z, ρ , θ , ϕ]

COR_RESET

MOVR_TCS [X, Y, Z, ρ , θ , ϕ] [speed = SLEW|TRACK|vel]

MOVA_TCS [X, Y, Z, ρ , θ , ϕ] [speed = SLEW|TRACK|vel]

MOVR_TRK [X, Y, ρ , H₁, H₂, H₃, H₄, H₅, H₆] [SLEW|TRACK|vel]

MOVA_TRK [X, Y, ρ , H₁, H₂, H₃, H₄, H₅, H₆] [SLEW|TRACK|vel]

GET_DATA [data_ID1] [data_ID2] [data_IDn]

GET_PARM [parm_ID]

SET_PARM [parm_ID] [parm_value]

INIT [axis | ALL]

Watchdog command

Trajectory “go” command?

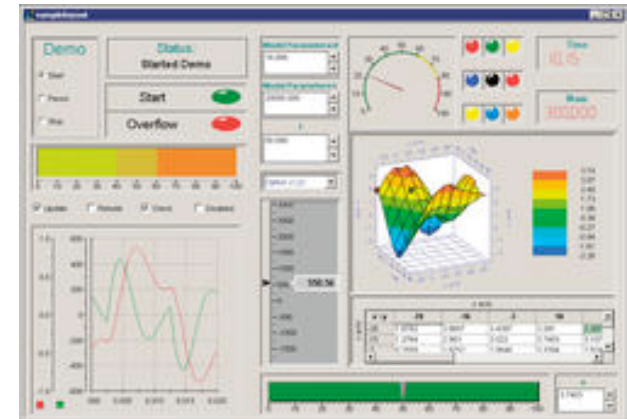
Tracker API

1. Does API provide commands necessary to implement all use cases?
2. Tracker communicates to TCS and Engineering Logger using standard ASCII strings (no binary data, except possibly a low-latency data-dump socket)
3. Does the “Idle” state imply brakes on?
4. When a relative or absolute move completes, do we hold, or apply brakes?
5. In the presence of a real mount model, we need to specify (X,Y,Z,rho,theta,phi) and not just (X,Y,rho)?
6. We need to be able to specify relative or absolute moves in both TCS coordinates and Tracker coordinates. Also, we need to be able to specify TCS coordinates with and without applying the mount model (whatever that means, exactly). What does it mean to turn off the mount model?
7. Trajectories are always specified in ideal tracker coordinates, which implies that the TCS is applying a mount model to take care of things like structure deformation, and the Tracker is taking care of things like encoder zeropoints and scale factors. It is still unclear exactly what parts of the mount model go where.
8. What are our options for the velocity argument for the move commands?
 - That is, do both slew and track motors have a range of speeds, and if so, what is that range?

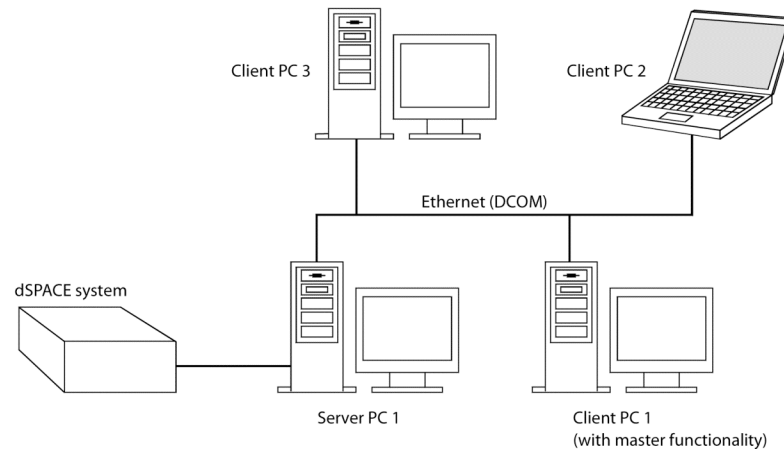
Tracker Encoders

- How will we use absolute vs. relative encoders?
 - Relative encoders are more accurate, but require movement to initialize
 - Absolute encoders are less accurate, but come up knowing position
 - Are there still absolute encoders in the plan?
- Use absolute encoders to determine if it is safe to move tracker
 - So that the relative encoders can be initialized
 - Can also compare absolute encoder readings on power up to those stored in the dSPACE persistent memory
 - If similar, tracker has not moved and we are confident where we are
 - If different, we are confused and require human intervention before proceeding
- Would not use absolute encoders are part of closed loop operation?

- Tracker system components:
 - dSPACE box
 - Real-time system
 - dSPACE host - Windows PC
 - MATLAB / Simulink
 - To program real-time system
 - ControlDesk
 - “Engineering Interface”
 - TCS - Linux PC
 - Trajectory generation
 - Software handpaddle
 - Operations interface
 - Laptop – Windows or Linux
 - MATLAB / Simulink, or
 - ControlDesk, or
 - TCS
 - Hardware handpaddle

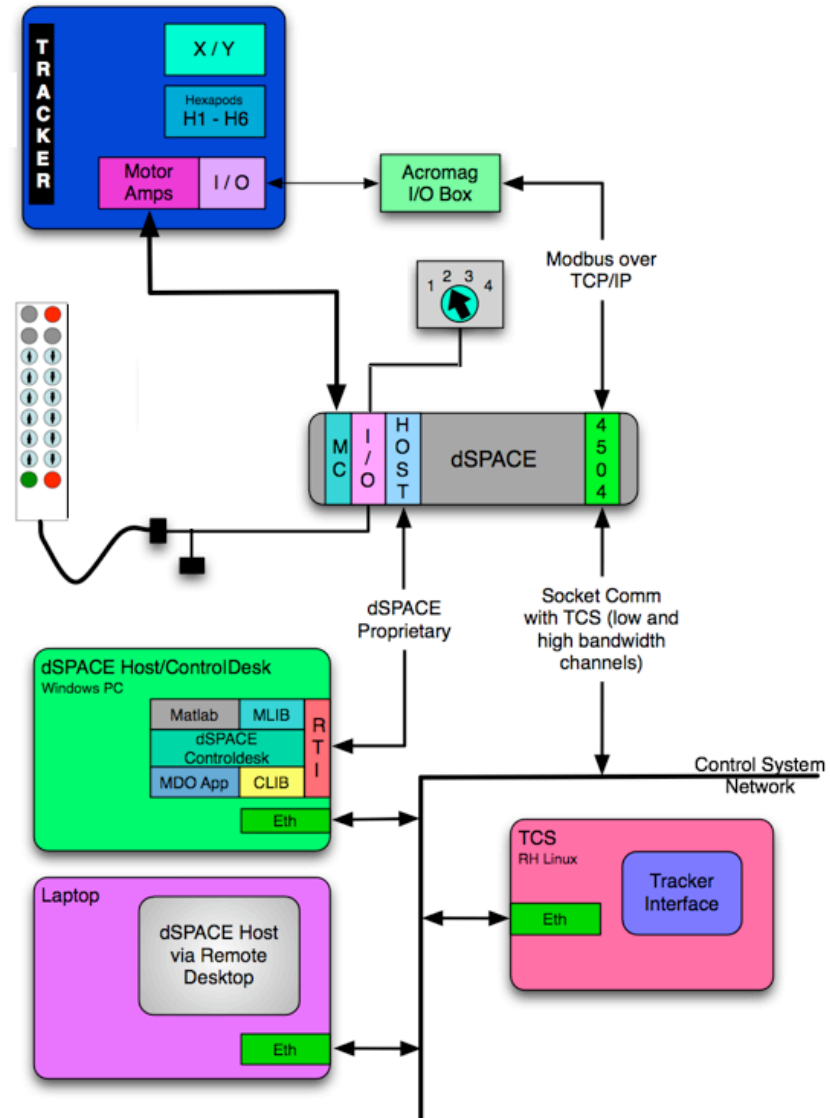


ControlDesk

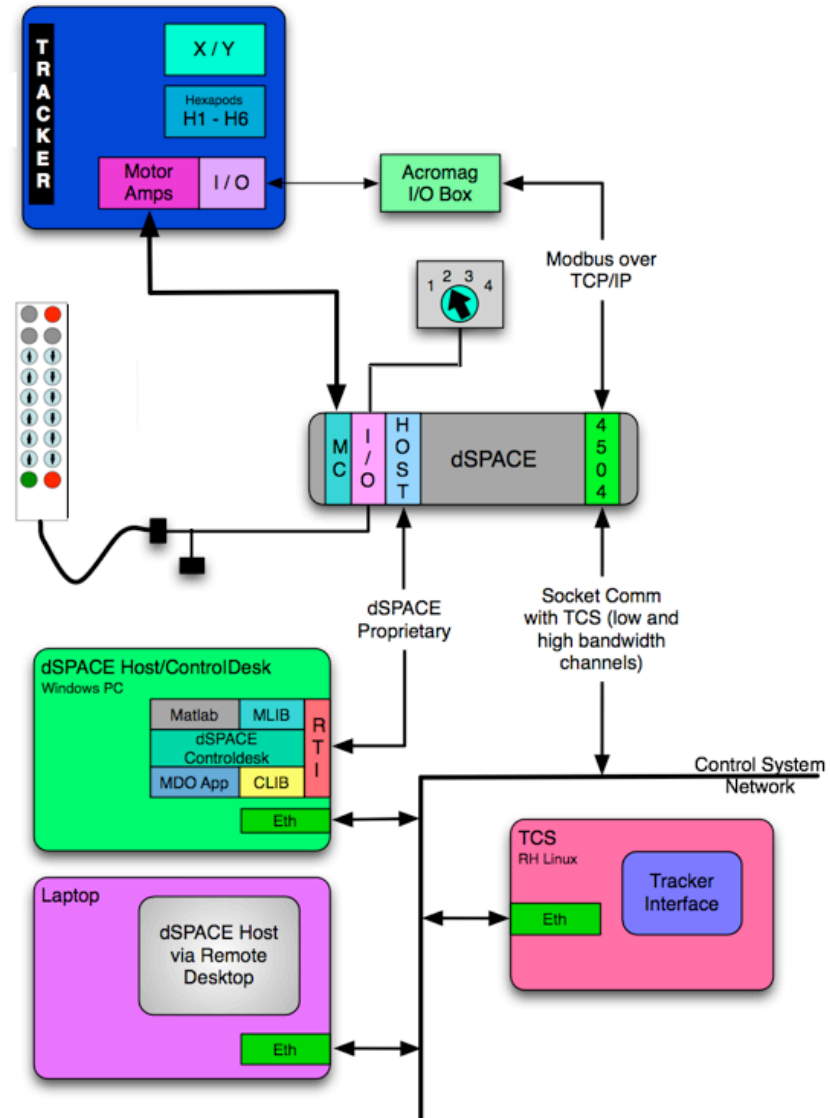


Accessing the dSPACE box from more than one system

1. Can the proprietary link between dSPACE box and ControlDesk PC be over standard ethernet instead?
 - dSPACE says yes; Easier to maintain, plus see below
2. Can multiple instances of ControlDesk talk to one dSPACE box?
 - dSPACE says yes, but one is server and the rest are clients (any better than VNC?)
 - Would be useful especially if possible over (wireless) Ethernet laptop in dome, in addition to PC display in control room, for instance
 - How do we mediate access to the dSPACE box?
 - Only one computer at a time should be authorized to command moves
 - Physical switch (or rotary knob) connected to dSPACE box?
 - Prefer *not* to have this set through the ControlDesk interface since that should not have to be up to operate tracker (Could do in TCS, though?)



3. Are people actually interested in a "read-only" mode for the engineering interface? Or for the TCS?
 - Or can any routine data display just be handled through TCS?
 - If so, is there interest in operating TCS in a "read-only" mode while some other computer drives?
 - Is this actually possible?
4. Can two computers connect to the dSPACE box over ethernet at the same time?
 - The use of the hand paddle while TCS eavesdrops would be a special case since the hand paddle is directly connected to the dSPACE box
 - Regardless, the ControlDesk interface may need 2 modes:
 1. One that can monitor things, but not change values (like motion control parameters)
 2. One that can do anything



Telescope Control System (TCS)

1. Trajectory generation strategy

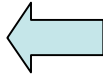
- Is there a preferred number of trajectory points to send at one time?
 - Could precompute a large number of trajectory points and send in advance
 - Then Tracker can validate entire trajectory before starting
 - » Is this the desired behavior? Or do we prefer to execute the valid points and stop?
 - Wastes time when we recompute the trajectory for an offset along the sphere
 - » But we only do that once or twice at the start of a trajectory
 - Could just send a few points at a time (“Follow The Carrot”)
 - How many points does CEM really need in advance?
 - Trajectory points still have an associated high-precision time to hit

2. Use TCS to initialize / reset Tracker parameters? Or vice versa?

- Need an easy way to edit / store / recall parameter sets
- Nice to have some means to read parameters from a disk file
 - dSPACE box has persistent memory, but no disk drive
 - Cumbersome to edit parameters from dSPACE Host PC
- Could include software limits, etc.
- Inverse: download parameters from *Tracker* to *TCS* at runtime
 - Helps make sure both systems are synchronized, but see above

Telescope Control System (TCS)

3. Functions in the current TCS that we could drop:

- Display of weather information
- Database function (star catalogs) 
 - e.g. Next...Star...FK5
- Calculation of planetary ephemerides
 - We plan to import tables of positions in standard formats instead
- Optional display of coordinates in obscure systems
 - e.g. ecliptic or galactic coordinates
- Ability to define reference points, wobble vectors

4. Functions that needed to be added:

- Audio alarms (need list)

Telescope Control System (TCS)

5. What functions / capabilities are needed for the "engineering TCS" (or maybe "TCSlite")?

(That is, the initial version of TCS that we use to debug the tracker at CEM)

- Calculate special trajectories
 - Like what?
- Move at constant rate in some axis?
 - Actually specify the exact rate (not just slew/track)?
- Engineering hand paddle
 - Jogs in any/all axes?
- Diagnostic plots (of what?), with features like:
 - (auto)scaling?
 - Logging?
 - Smoothing?
 - Rolling strip charts?
- Simulated metrology inputs
- Any of the functions we add now will be available in the final TCS

Telescope Control System (TCS)

6. What functions are needed in the ControlDesk engineering interface?
 - And why implement them in ControlDesk rather than in TCS?
 - Both ControlDesk and TCS run on additional computers which access the dSPACE box over a comm link
 - Access speed and latency might be better for ControlDesk over proprietary link, but the TCS binary, large buffer data-dump socket should mitigate that, making these perform similarly (needs testing)
 - CEM will need certain functions in the lab, and will find it easiest to write these in the MATLAB / Simulink / ControlDesk environment
 - However, once installed at HET, ControlDesk is problematic
 - Only runs on a Windows (XP?) PC
 - Connected via a proprietary interface that looks like ethernet, but is not
 - An "engineering TCS" could be run from a laptop in the lab or dome or wherever using the same ethernet interface that we will use for TCS in routine operation, avoiding the ControlDesk proprietary interface issue
 - TCS, written in C++, is easier for our staff to maintain long term

TCS User Interface

- What are some of the likes/dislikes WRT the current user interface system?
- Distributed GUIs or integrated? Tabs vs. Tiled?
- Consolidation of graphical data (plots, etc) on one screen, with inputs on another?
- What "modes" does the software have? i.e., One set of UI screens for doing maintenance, another set for normal science, etc.
- Command line interface?
- Scripting? What language? Python? Tcl?
- General input from TOs, RAs, HET staff?

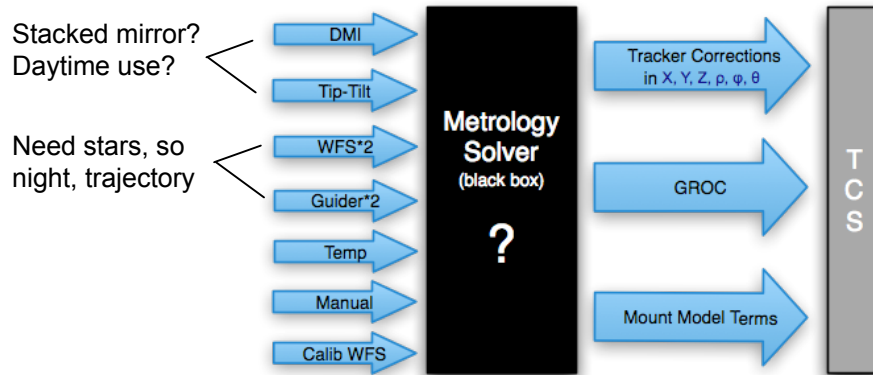
New Procedures

1. How do we want the new e-stop system to work?
 - Is there a separate lockout/tag out system?
 - If so, how do the two relate?
 - OSHA reference for lockout/tag out
 - What is the detailed sequence of events that happen when e-stop is pressed?
 - How do software e-stop buttons relate to the hardware e-stop system?
 - Are they effectively the same?
2. What else?

End of day 1

Payload Alignment System (PAS)

1. Metrology and guide correction issues

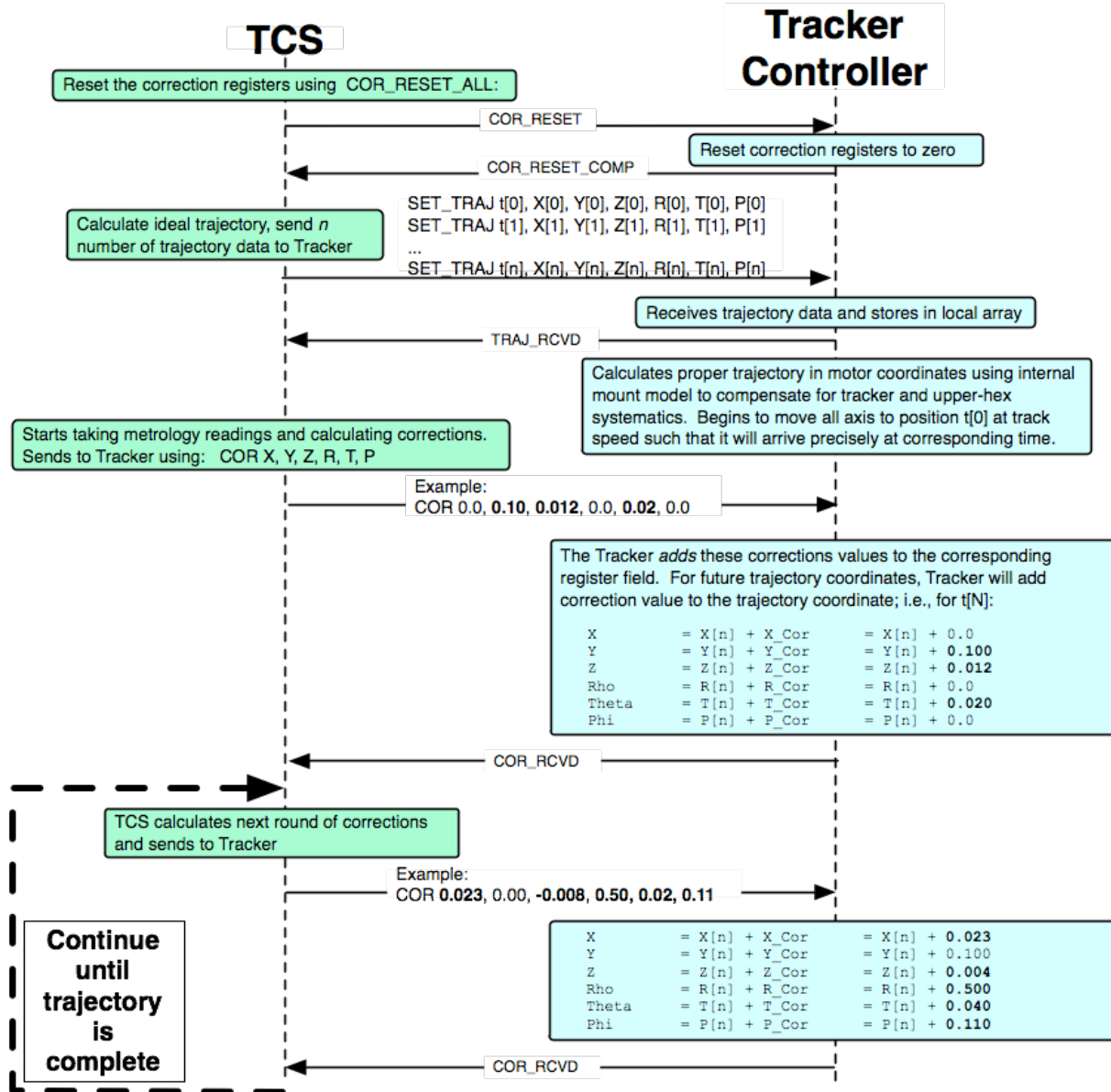


Function	Guider	WFS	DMI	TTS
Position on sky (x,y)	S, C			
Rotation	S, C			
Focus		S, C	S, C	
Primary Mirror GRoC / Plate Scale	S	S, C	S, C	
Tip-tilt of corrector		S		S, C
Image quality	S			
Transparency	S			

S = Sense C = Control

- Need to know how to compute the corrections in each tracker coordinate from available measurements
 - From the spot centroids or whatever
- How independent are the measurements?
 - Also, is there an order of operations such that we first correct one axis, then another?
- When does a telescope move imply a new position on the sphere, and hence a new trajectory calculation?
 - Not for a typical guide correction, which is meant to bring the calculated trajectory in line with the actual sky, but yes for an offset on the sky (acquisition / blind offset)?
- Do we need to keep track of the cumulative corrections in TCS?
- How does the mount model factor into trajectory corrections?
 - Is there any way to work in the cool Observatory Sciences idea where guide corrections actually adjust mount model terms?

Trajectory Correction Strategy

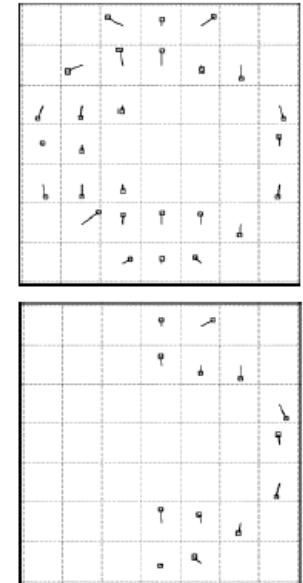
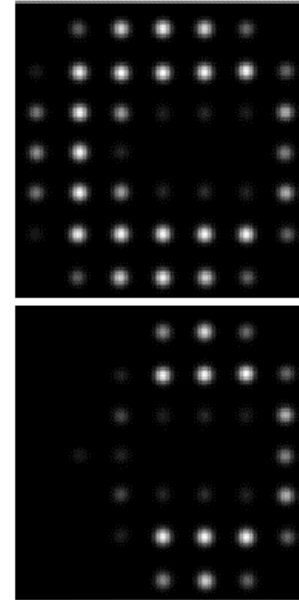


Trajectory Correction Registers					
X_Cor	Y_Cor	Z_Cor	R_Cor	T_Cor	P_Cor
N/A	N/A	N/A	N/A	N/A	N/A
0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.100	0.012	0.000	0.020	0.000
0.023	0.100	0.004	0.500	0.040	0.110

Payload Alignment System (PAS)

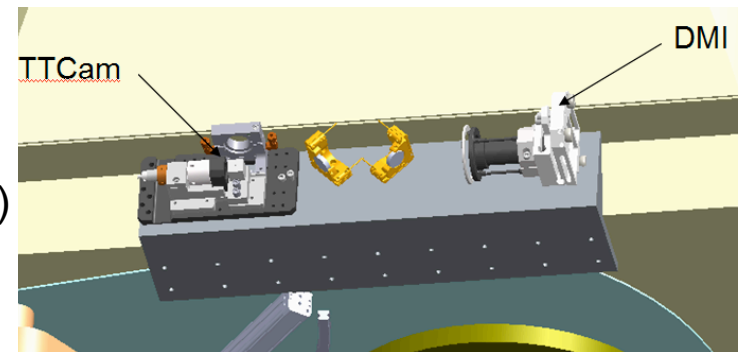
1. Metrology and guide correction issues (cont.)

- How exactly does the WFS work? What are its outputs? Is SW in-house?
- How does the “Calibration WFS” differ from the other WFS?
- How exactly does the TTCAM work? What is its output? Is SW commercial or in-house?
- Are there 1 or 3 TTCAMs?
If 3, are there 3 separate controllers for the software to talk to?



Or a single controller with 3 measurement heads?

- Is trending analysis necessary between measurements?
 - e.g. for the “slow” systems (TTCAM, DMI)
 - Where does the 10-second cycle time for these instruments come from?
 - Can/should they go faster?



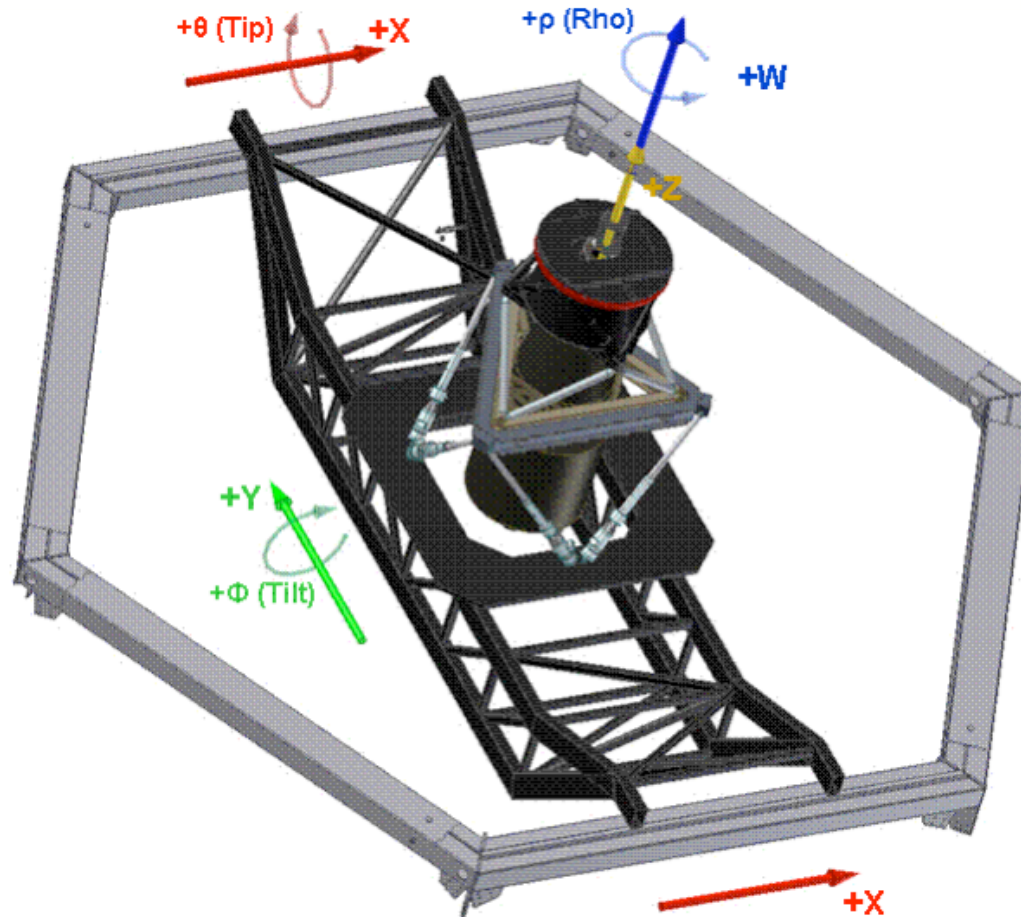
Order of Operations

Example: Using Acquisition Camera

Duration (sec)	Actions	
5	Acquire acquisition camera image	
5	Readout acquisition camera	
1	Determine tracker corrections	
1	Move tracker by as much as 2.05' (note the acquisition camera FOV is 2.90' by 2.90')	
5	Acquire guide camera images	
1	Readout guide cameras	
1	Determine tracker corrections	
0.5	Move tracker by as much as 16" (note the guide camera FOV is 22.60" by 22.60")	19.5 sec
10	Acquire WFS and guide camera images while moving the acquisition camera pickoff mirror out of the WFC FOV	
1	Readout WFS and guide cameras	
2	Determine tracker corrections	
0.5	Move tracker by as much as 16"	13.5 sec
10	Acquire WFS and guide camera images	
1	Readout WFS and guide cameras	
2	Determine tracker corrections	
0.5	Move tracker by as much as 16"	13.5 sec
10	Acquire WFS and guide camera images	
1	Readout WFS and guide cameras	
2	Determine tracker corrections	
0.5	Move tracker by as much as 16"	13.5 sec

Payload Alignment System (PAS)

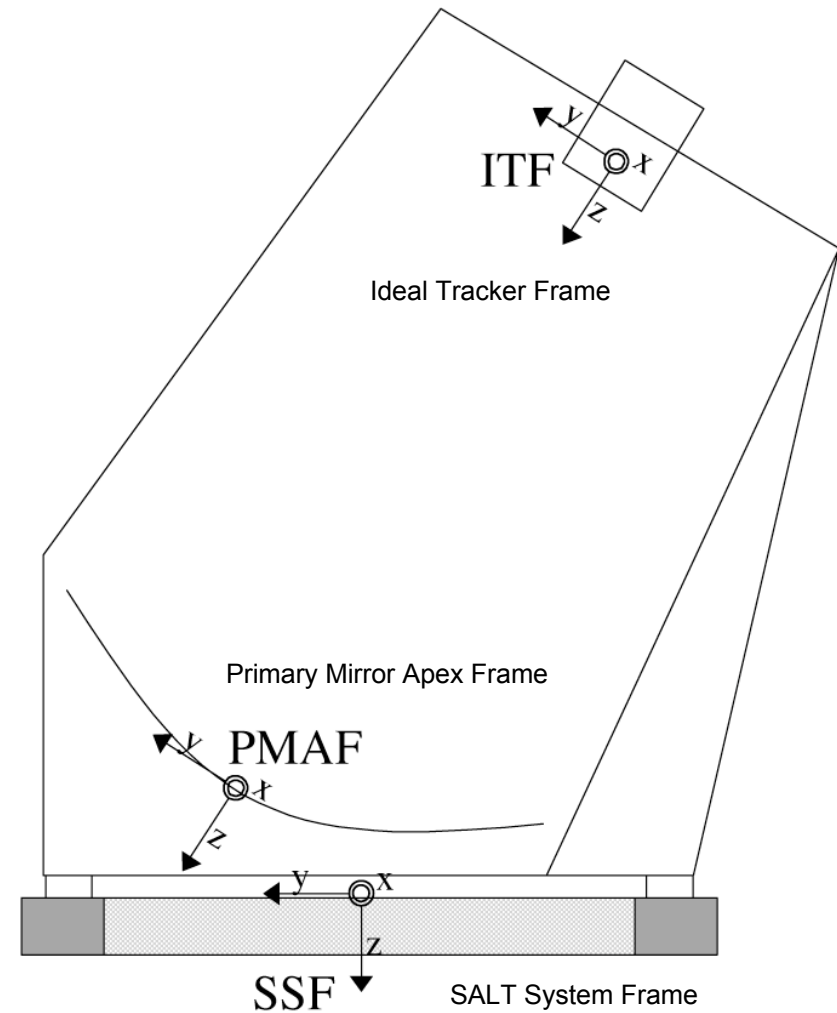
Understanding Z vs. W axis



From the WFC Specification

Payload Alignment System (PAS)

2. Should we change the way we handle changes to focus?
 - Existing code just makes a delta to Z (and assumes $\Delta DMI = \Delta Z$?)
 - But DMI measures distance to mirror along W axis (angle β to Z)
 - $\Delta Z = \Delta DMI / \cos(\beta)$, $\beta = 8.5$ deg max, implies a max error of 1.1%
 - If we make movements in Z, what corresponding movements do we have to make in other axes?
 - Any work on the current system can serve as a prototype for the new system
 - Must capture and transfer any improvements made to existing system. Is there a plan to work on this now?

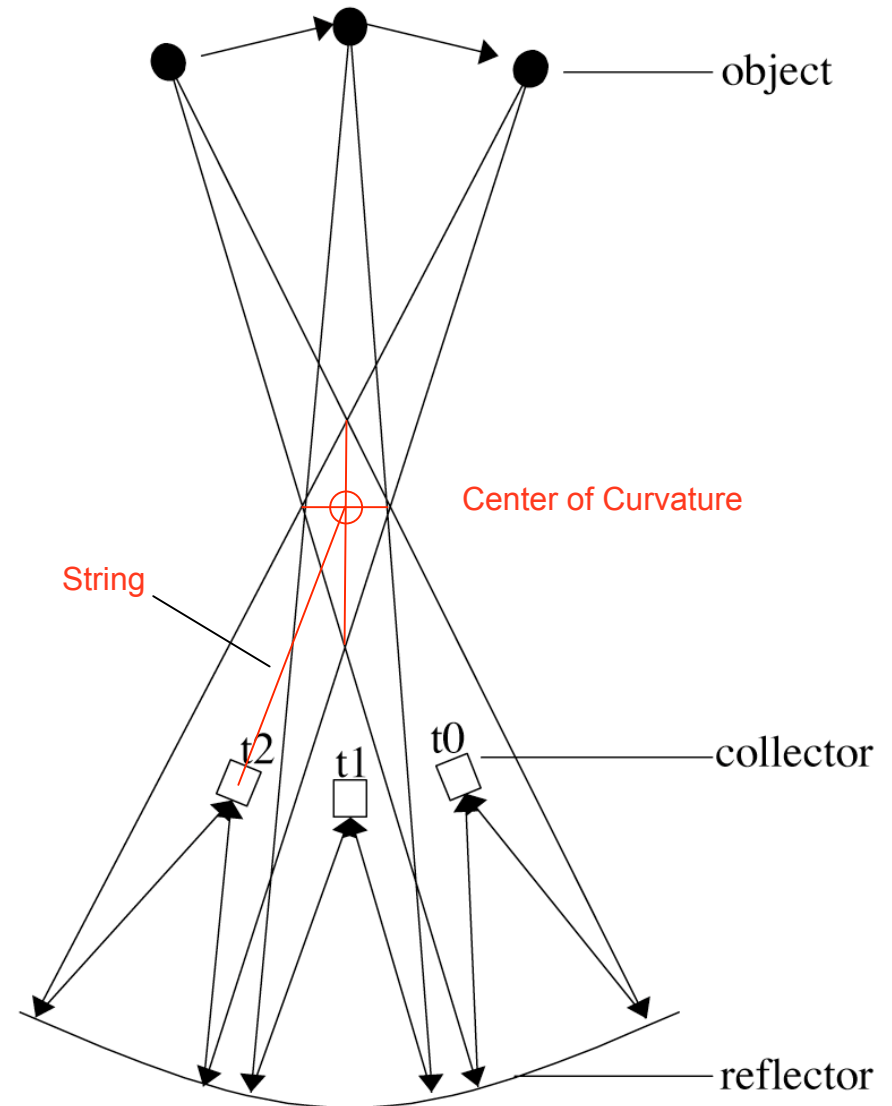


From SALT Documents

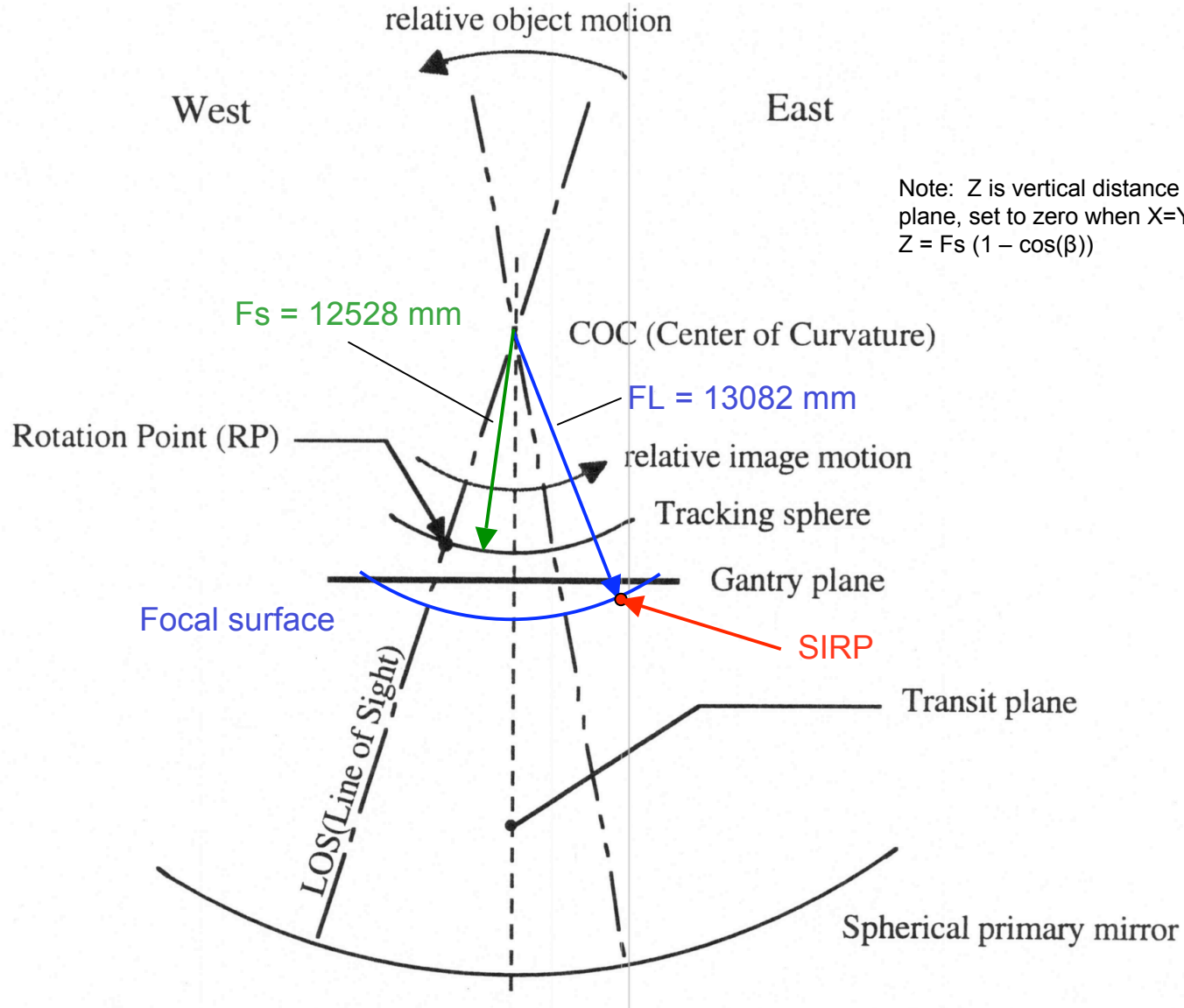
Payload Alignment System (PAS)

3. Currently we rotate tracker about one point, guide about another
 - What does that mean to the correction calculations?
 - SIRP vs. coma neutral point?
 - Do we need to be able to adjust location of SIRP? On the fly?
 - Fs vs. Focal Length (see next)
 - How does the difference relate to SIRP?
 - Fs will change for new Tracker?
 - This affects TCS trajectory calc
 - Also the Tracker software? How?
 - How does this relate to the hexapod transform?

“Can on a String”



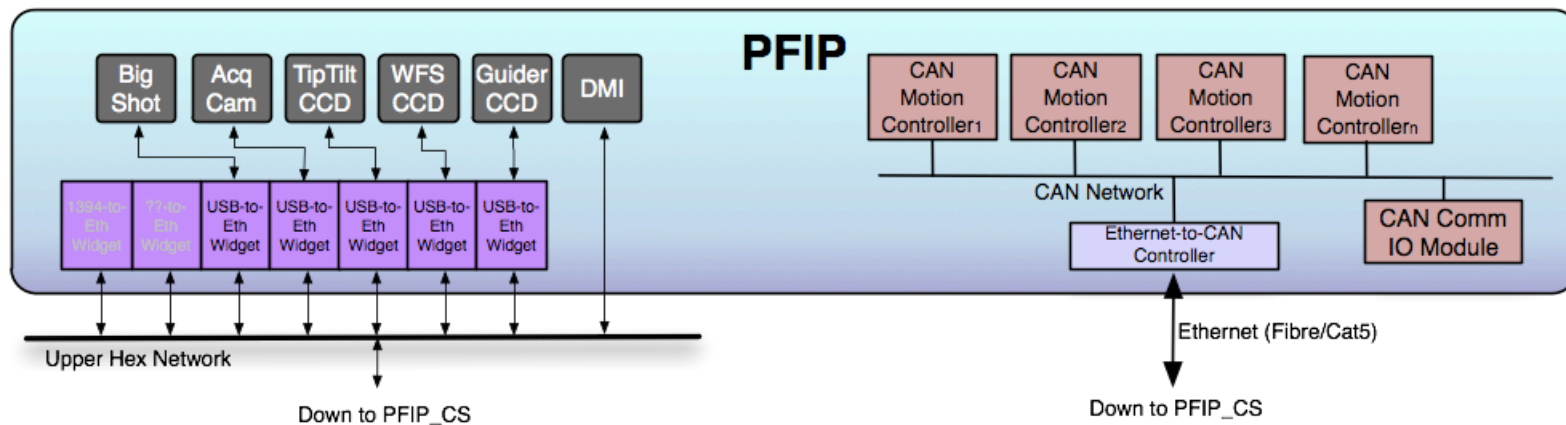
Tracker Rotation Point vs. SIRP



Note: Z is vertical distance of RP from Gantry plane, set to zero when X=Y=0 with Fs,
 $Z = Fs (1 - \cos(\beta))$

PFIP

1. Discuss the current DMI and TTCAM parameters and what can be / is routinely adjusted
2. What new devices might be added to top end after initial deployment (e.g. more capable Wave Front Sensor or video cameras to monitor motions)?



- Ideally get some buy-in to our approach to handling PFIP devices, with the goal of handling future devices the same way

3. Is CEM doing mechanics for some of the PFIP devices? Motion control?
4. How do we register the Guide/WFS probes to the sky / IFUs?

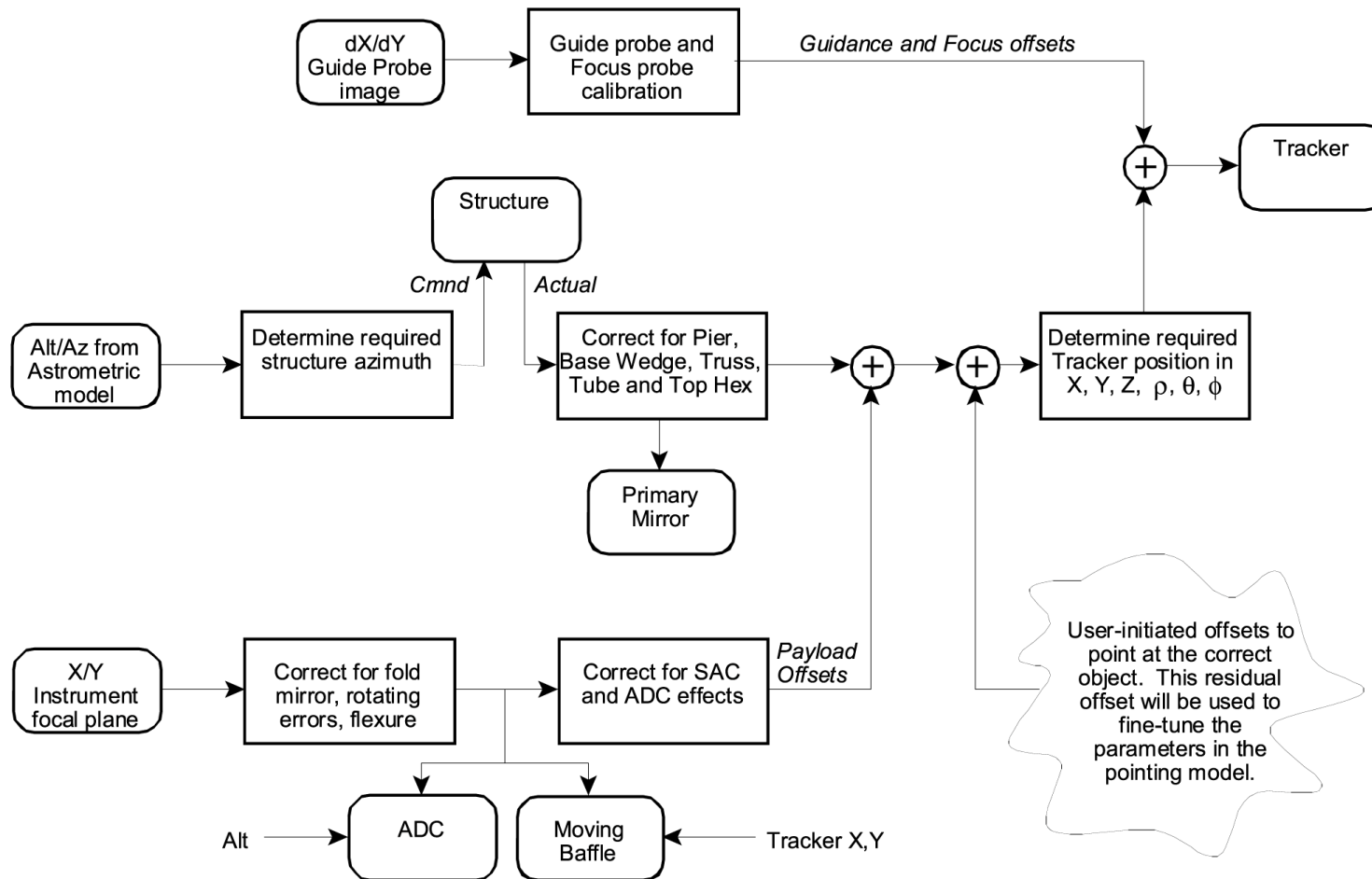
Mount Model

SALT Astrometric Pointing Model:

- FK4 Precession to B1950
- FK5 Precession to J2000
- IAU 1980 Ecliptic to FK5 Equatorial
- IAU 1958 Galactic to FK4 B1950
- FK4 B1950 to FK5 J2000
- Heliocentric parallax
- Geocentric parallax
- Light deflection
- Aberration
- Precession from FK5 J2000 to date
- Nutation
- Earth's rotation
- (HA, Dec) to (Az, El)
- Refraction

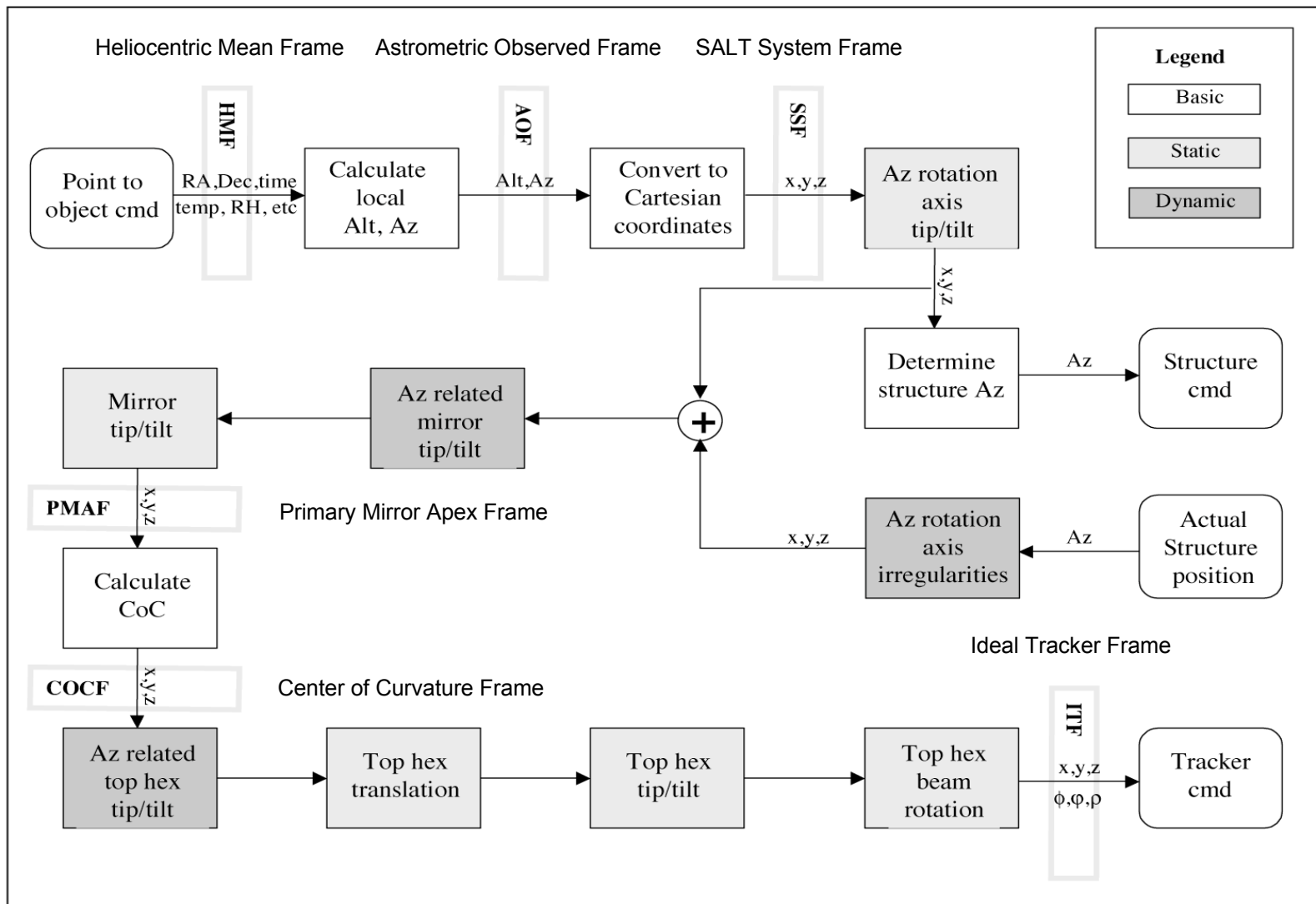
Mount Model

SALT Pointing Flow Chart, Overview:

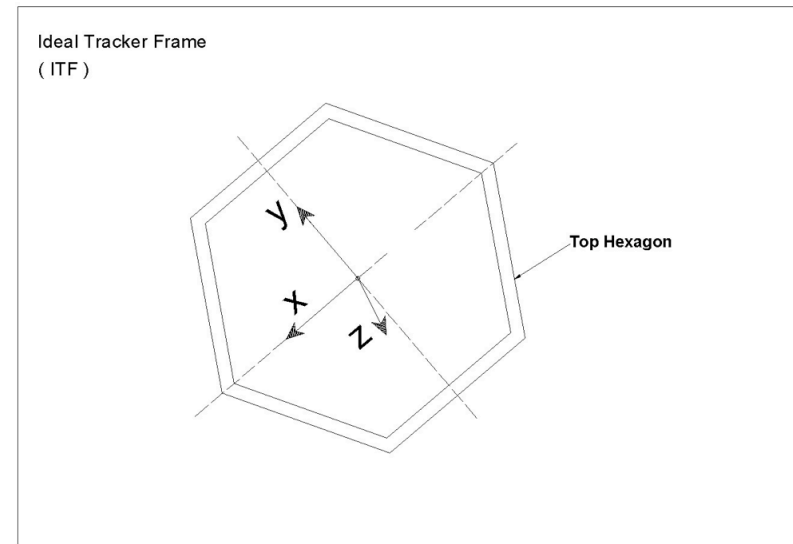
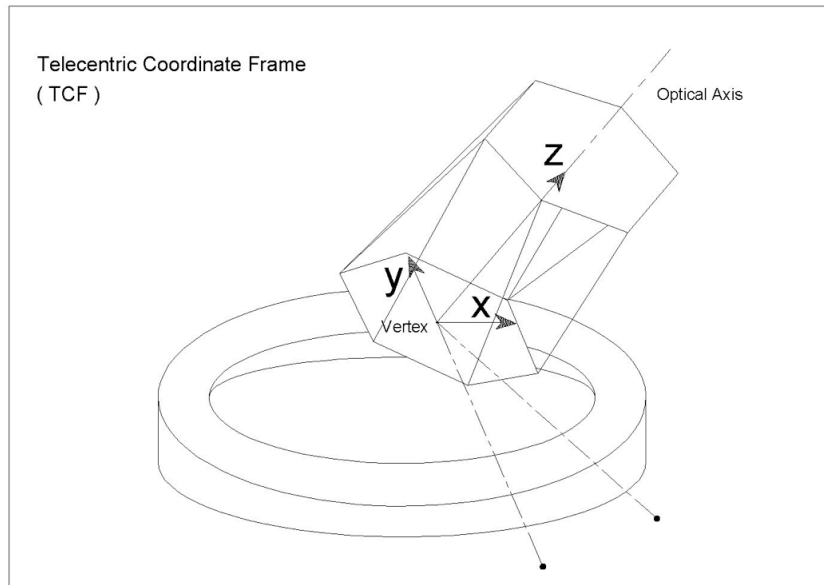
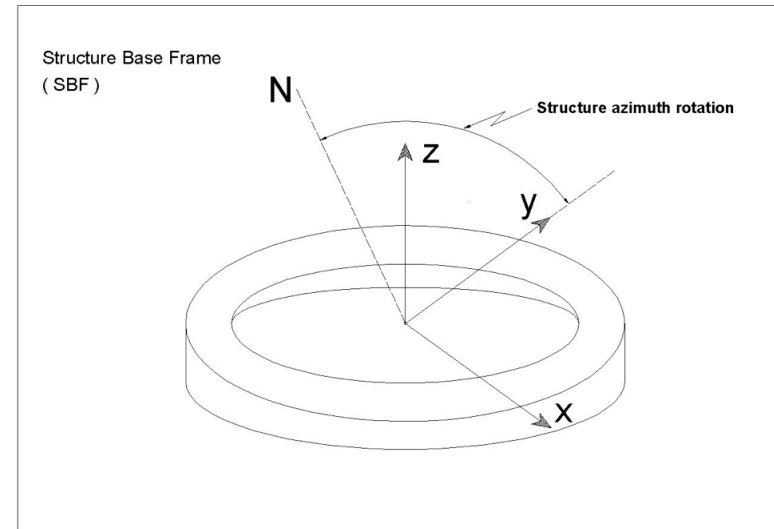
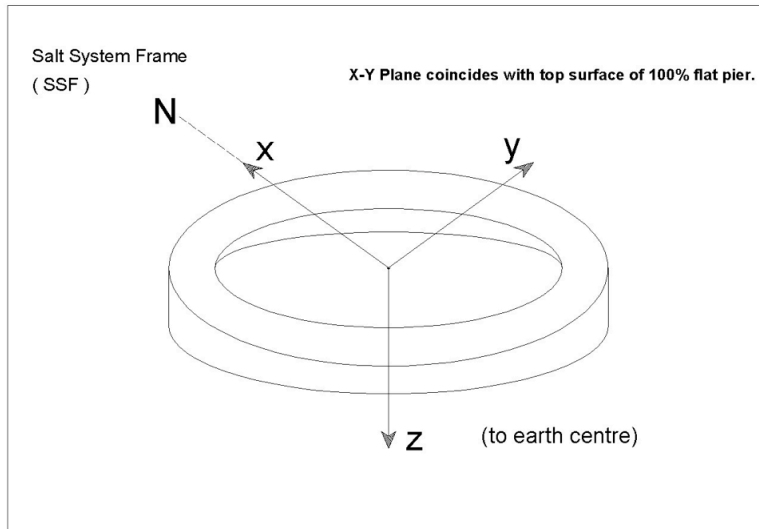


Mount Model

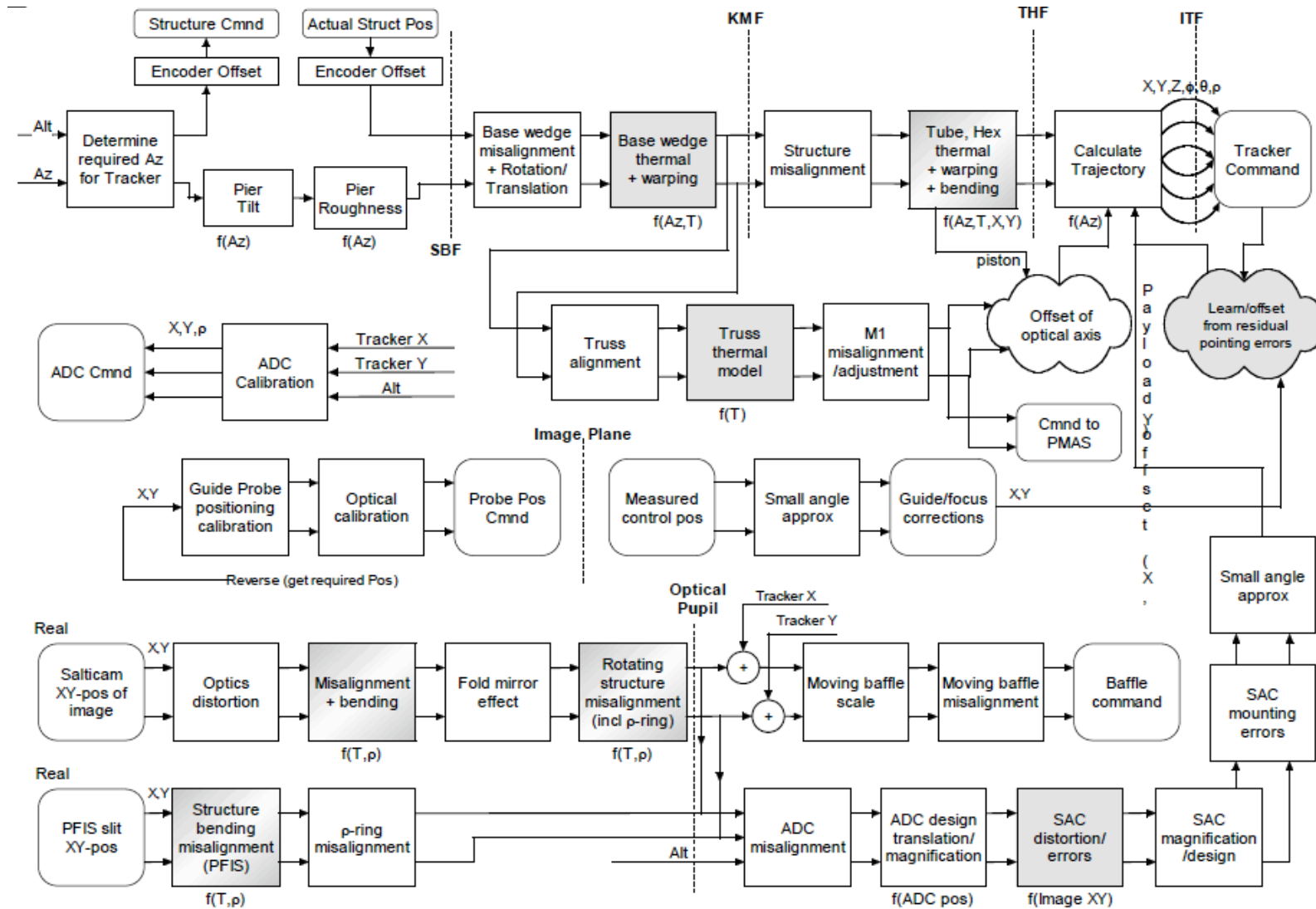
SALT Pointing Model Flow Chart, More Detail, Reference Frames:



Reference Frames



Mount Model (Detail)



Mount Model

1. What physical issues are we trying to address in the mount model?
 - Non-flat pier, i.e. adjustments to altitude as a function of azimuth
 - Rail curl
 - Tracker support rails sag under tracker weight (presumably worse in the center of range)
 - Bending of upper hex as tracker moves?
 - Maybe another example of altitude changing, this time as a function of X and Y
2. How can we measure which parts of the mount model?
 - Ideal is to measure as much as possible in the lab
 - Or at least before mounting the tracker on the telescope
 - Or if after mounting, at least during the day
 - Which terms can be measured this way?

That is, which things can we expect not to change between lab and telescope?

What can we measure off sky?

Mount Model

3. General mathematical approach to mount model

- SALT idea where model is built up out of many simple rotations and tilts
 - Relative to specific reference planes or axes?
 - Which ones make sense?
 - What can Rich easily measure with the Sokkia?

Mount Model

In the end, we'll need a computation and measurement technique for each physical component of the mount model, as SALT documents here:

	Description	Dependence on other variables	Type*	Calibration method
1	Structure North misalignment	None	Offset	Theodolite survey, star tracker
2	Dome North misalignment	None	Offset	Theodolite survey
3	Pier Global tilt	Structure Azimuth	Axis rotation	Theodolite survey, star tracker
4	Pier flatness	Structure Azimuth	LUT	Theodolite survey, star tracker
5	Base wedge design tilt	None	Axis rotation	Design drawing
6	Truss design thickness	None	Axis movement	Design drawing
7	Truss/base wedge misalignment	None	Axis rotation	Theodolite, adjust Truss relative to Top Hex centre (ITF origin)
8	Truss/base wedge warping	Temperature, structure azimuth	Model or LUT	Monitoring mirror angle with temperature and structure az angle
9	Structure design misalignment	None	Axis rotation	Design drawing
10	Structure misalignment	None	Axis rotation	Theodolite survey, star tracker
11	Structure warping, bending	Temperature, structure azimuth, Tracker position,	Model or LUT	Surveying and using star tracker under varying temp conditions and tracker positions
12	M1 misalignment (mirror relative to Truss). Could be combined with item 7.	None	Axis rotation	Theodolite, adjust M1 segment relative to Top Hex centre (ITF origin)
13	Calculation of Tracker Commands	None	Axis rotation	None
14	SAC design image scale	None	Angular conversion	Sagem acceptance test documents
15	SAC image translation/defocus and axis-symmetric distortion	Tracker Tip/Tilt	LUT or model	Information provided by SAGEM
16	SAC mounting misalignment w.r.t. other payload parts and mounting ring	None	Axis rotations	Survey Payload in the lab
17	Fixed structure flexure	Tracker Tip/Tilt	LUT or model	?
18	Moving baffle installation misalignment	Non	Offset in X,Y	Survey in lab
19	ADC design effect on image location	Object Elevation, Tracker position	Model	Design drawing
20	ADC misalignment effect on image	Object Elevation, Tracker position	Model or LUT	Measure in lab
21	Rotating structure misalignment	None	Axis rotation	Survey in lab and on Tracker, finalise with guidance tests on sky (rho dependence)

Mount Model

Continued:

	Description	Dependence on other variables	Type*	Calibration method
22	Rotating structure flexure	Tracker Tip/Tilt/Rho	LUT or model	?
23	Fold mirror image inversion	None	Conversion	N/A
24	Fold mirror image distortion and translation	Station in use, mirror in use	Conversion	Survey in lab
25	PFIS mounting misalignment	None	Axis rotation	Survey and finalise with guidance on-sky (rho dependence)
26	FIF mounting misalignment	None	Axis rotation	Survey and finalise with guidance on-sky (rho dependence)
27	SALTICAM mounting misalignment	None	Axis rotation	Survey and finalise with guidance on-sky (rho dependence)
28	SALTICAM optics image distortion	None	LUT	Measure in Lab
29	Global residual correction	Structure Azimuth, Tracker X, Tracker Y, Tracker Rho, Temperature, field position, focal station	Statistically adjusted model (e.g. Kalman filter)	Each operator adjustment can be used to adjust this as can the guidance corrections. Initially this adjustment will be off-line

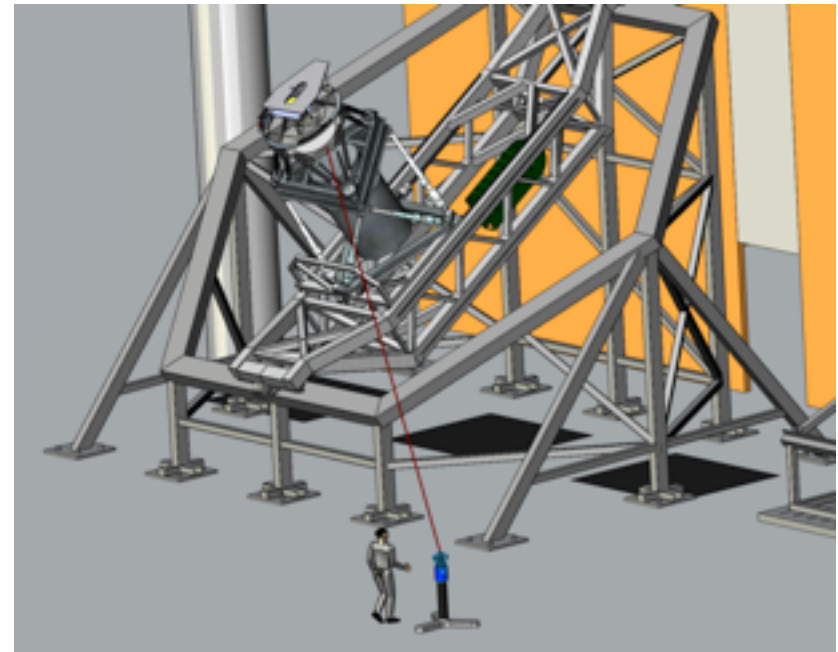
NOTES*: The type of correction applied is shown here for information only, as an initial guess.
 LUI – Look-up table
 Axis rotation – Euler transform of position and/or rotation
 Conversion – simple $ax + b$ calculation
 Model – more complex numeric calculation

Mount Model

4. When and where does the mount model get applied?
5. What does it mean to turn off the mount model?
 - i.e. current tracker engineering interface is often used rather than TCS just because TCS always applies the mount model
 - Can easily have TCS not apply the model but what exactly does this mean?
 - Are there different parts that one turns off under different conditions?
6. Goals/status of Jim's latest work on mount models?
 - What work is going on now? Planned?
 - How will this work affect what HETDEX team is working on?

Pre-Deployment Testing

- How can we do realistic tracker testing in the lab?
 - Can we rig up optics to make the DMI or TTCAM really work?
 - i.e., can we overcome the limited capture range of the hardware?
- How will we approach the tracker testing at CEM?
 - Rich's flat bed test plan (RFBTP)
 - Does this measure the performance we care about?
 - If not, how?
 - Is there any way to actually track a star on the sky?
 - What type of simulation objects can we use to inject noise into the system?



Post-Install Testing

- Once the new tracker is installed on the telescope, what can we measure to reduce the degeneracy of mount model terms and motions on the sky?
 - What can we physically measure?
 - Referenced to where?
 - Preferably during the day?
- For example, it is helpful to register the upper hex to the floor?
 - And watch it deflect under the tracker's weight
 - Is this worth trying now, to get an idea of what this looks like?
- Goal is to reduce the number of things we have to do during our very short permitted two months of downtime

Wrap up...

End of day 2

Thanks to all for your time!