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Spacecraft Status and Constraint Look Ahead

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October 22, 2013

Purpose and Agenda

Purpose:

Provide an update on the status of the Chandra Spacecraft and the impact of evolving constraints on observing capability

Agenda:

- Overview of Spacecraft Health
- Current Issues Impacting Observing Capability
- New and evolving constraints
- Observing capability impacts

Spacecraft Health

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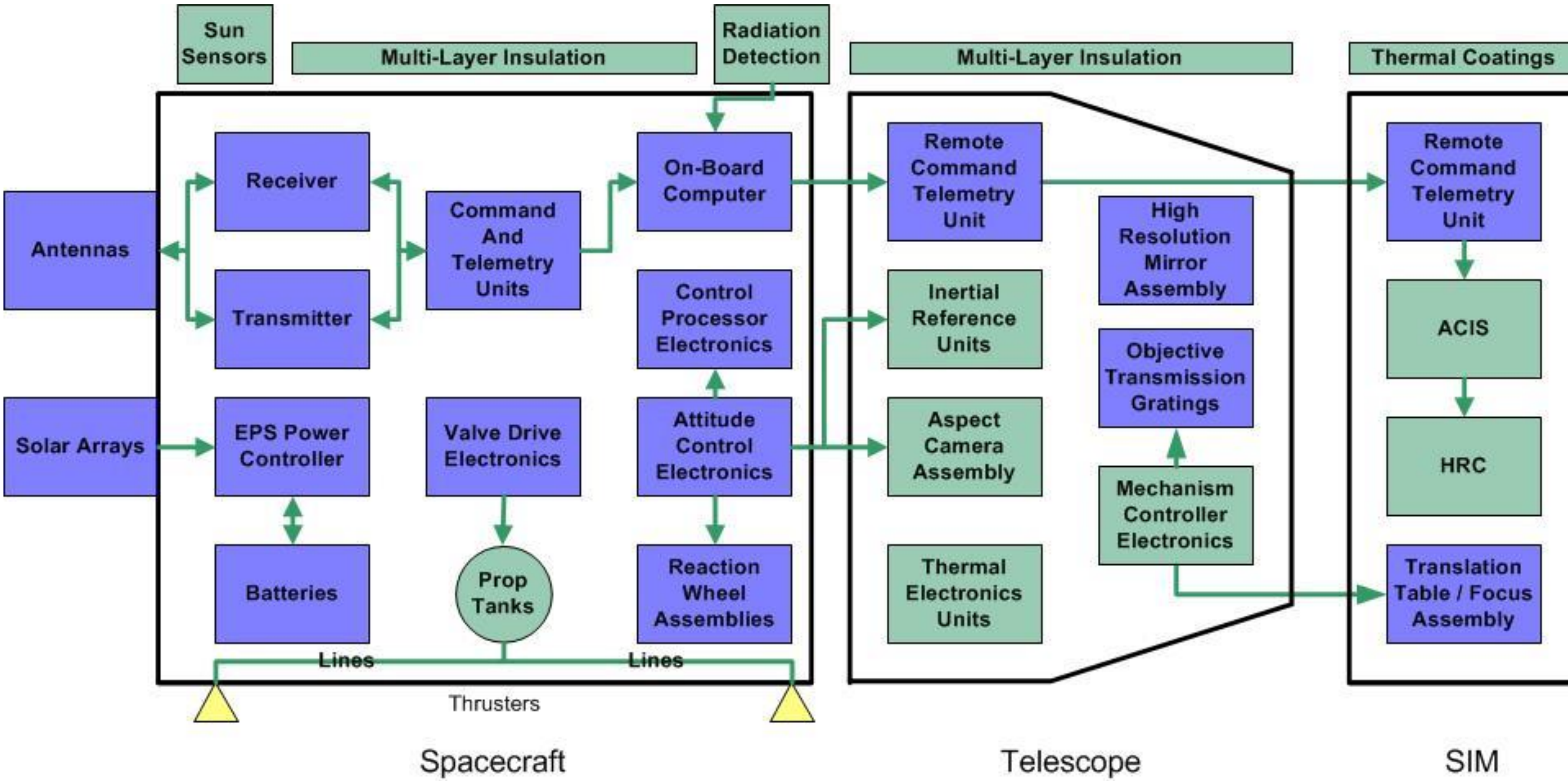

Key: blue = no known problems; green = minor problem but meeting all requirements; yellow = moderate problem with manageable performance effects; red = major problem affecting performance;

Spacecraft Status - Thrusters

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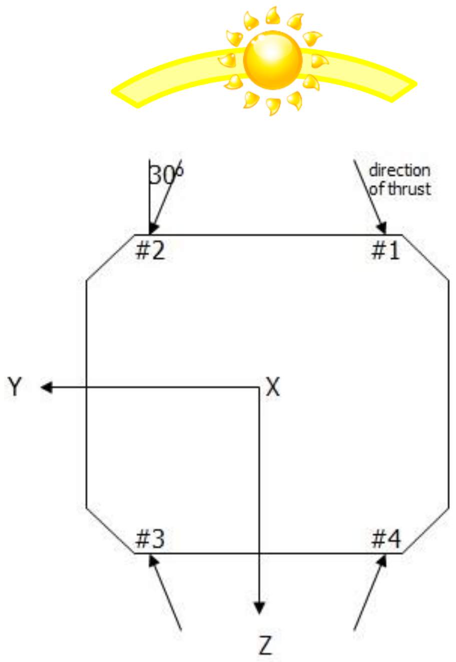
- A-side thrusters have 14 years of use
- Thruster A1 started showing signs of degradation in the catalyst bed
- If catalyst bed allowed to degrade too far introduces risk of “wash-out”
  - Worst-case, wash out can cause catastrophic thruster failure
- Swapped to B-side to preserve A-side for use in Safe Mode



- During checkout thruster B2 did not produce any thrust
  - Investigation underway
  - Preliminary analysis pointing to failure of an electrical connection
- Full unload capability requires all four thrusters
  - Nominal operations manageable with three thrusters
  - Contingency operations requires four working thrusters

Spacecraft Status - Thrusters – Plan Forward

- Remain on MUPS-B for nominal operations
  - Unloads must be planned carefully to eliminate use of thruster #2
  - Primary impact is to Mission Planning effort and ACIS FP temperature during perigee transit
- Keep MUPS-A for Safe Mode
  - Unloads in Safe Mode are critical to safety so we must do everything we can to maintain four thrusters available for use in Safe Mode
- Investigate allowing mixed configuration
  - Thrusters and electronics are not cross-strapped
  - There are options to patch the FSW to allow using thrusters from both banks as long as both VDEs are healthy
  - Must consider impacts to redundancy for safing
- Some historical success with planning attitudes to eliminate momentum unloads altogether
  - No unload capability compromises capability to handle contingencies
  - Highest impact likely to ACIS FP temp and MP effort
  - Some decreased ability for very long dwells possible
  - Next low perigee in 2023 would present significant challenges

Spacecraft Status – Sun Sensors & IRU

Sun Sensors

- Chandra has two sets of sun sensors, coarse (CSS) and fine (FSS)
- The CSS have no known issues
- Suspected stray light impingement on FSS-A caused a swap to FSS-B
- FSS-B operating well - no field of view (FOV) restrictions
- FSS-A still acceptable for use in Safe Mode – errors near FOV boundary

IRUs

- Chandra has two fully cross-strapped IRUs, each with two gyros
- Gyro current concerns in Gyro A1 caused a swap to IRU-2 in 2003
- Experiencing noise in current and bias of both gyros in IRU-2
- At present, noise levels are benign and not of concern to the vendor
- Gyro health is very closely monitored
- A low-level long-term effort to develop a one gyro control mode is underway

No capability or lifetime impacts due to current status of IRU or FSS

Spacecraft Status - Thermal Surface Degradation

- Degradation of thermal surfaces causing some components to heat beyond design expectations
- Attitude restrictions used to control component temperatures

Unit	Restricted to prevent	Risk of
PSMC, ACIS DPA	Exceeding qual test temperatures	Instrument Damage
MUPS	Restricted fuel flow during unloads	Ineffective momentum dumps Accumulation of damage
Fuel Tank	Exceeding tested temperatures for this type of tank	Crack growth in hydrazine tank (unquantified risk)
ACA	Increased background and warm pixel fraction	Degraded pointing performance, BSH
Central Cylinder, TEPHIN	Temperature excursions beyond flight experience	Unpleasant surprise
ACIS Focal Plane	Gain calibration out of spec	Science quality impact
PLINE	Frozen hydrazine in lines	Contamination with hydrazine

Thermal Constraint Pitch Sensitivity

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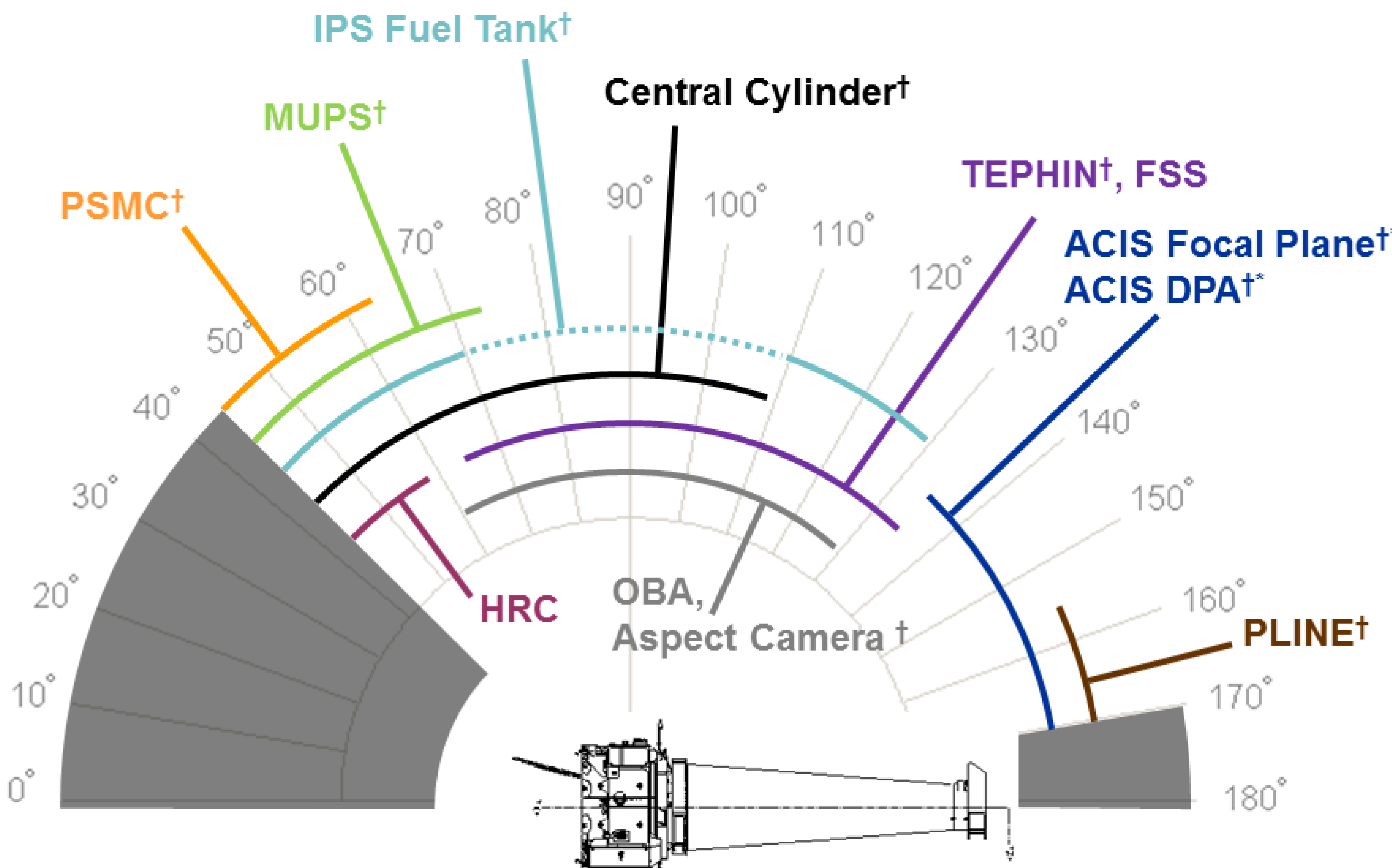

* Tail sun pitch is one of several factors affecting temperatures in this region

† Temperature in this region is managed via a formal restriction

Spacecraft Status – Aspect Camera

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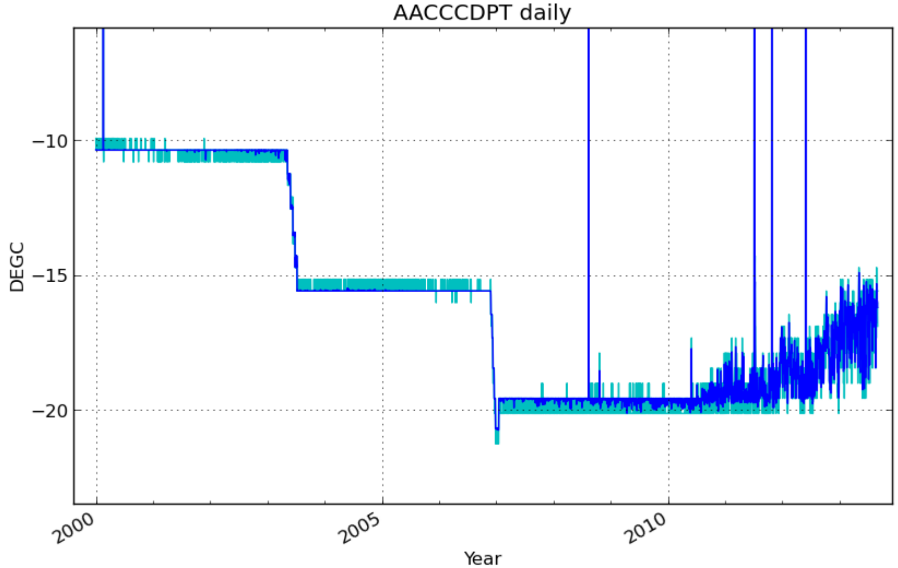
Higher ACA Body Temperature

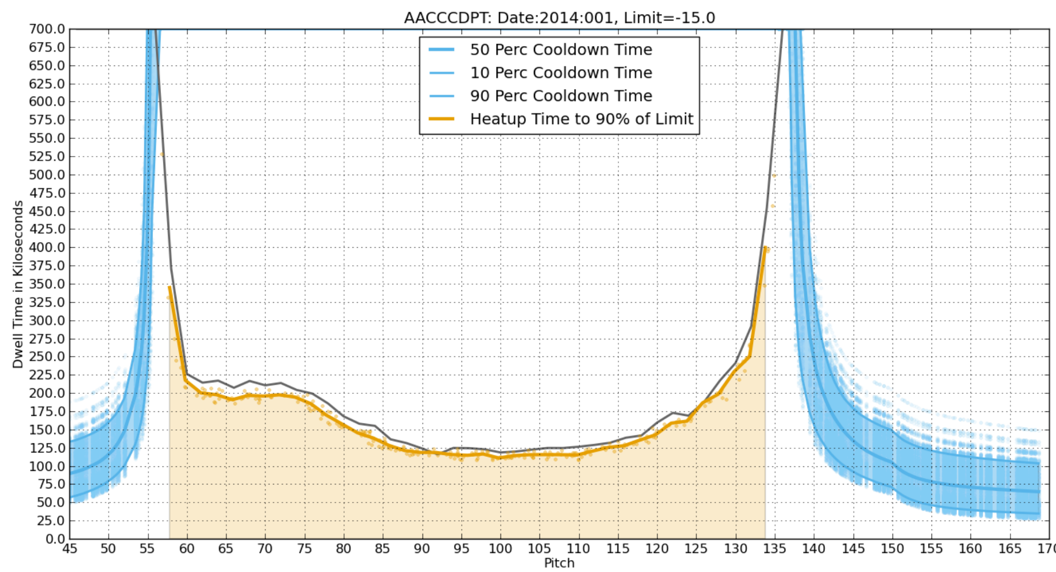
Can no longer maintain CCD temperature set-point

Increased warm and hot pixels

Reduced capability to track faint stars

Degraded aspect solutions and potential for safing action





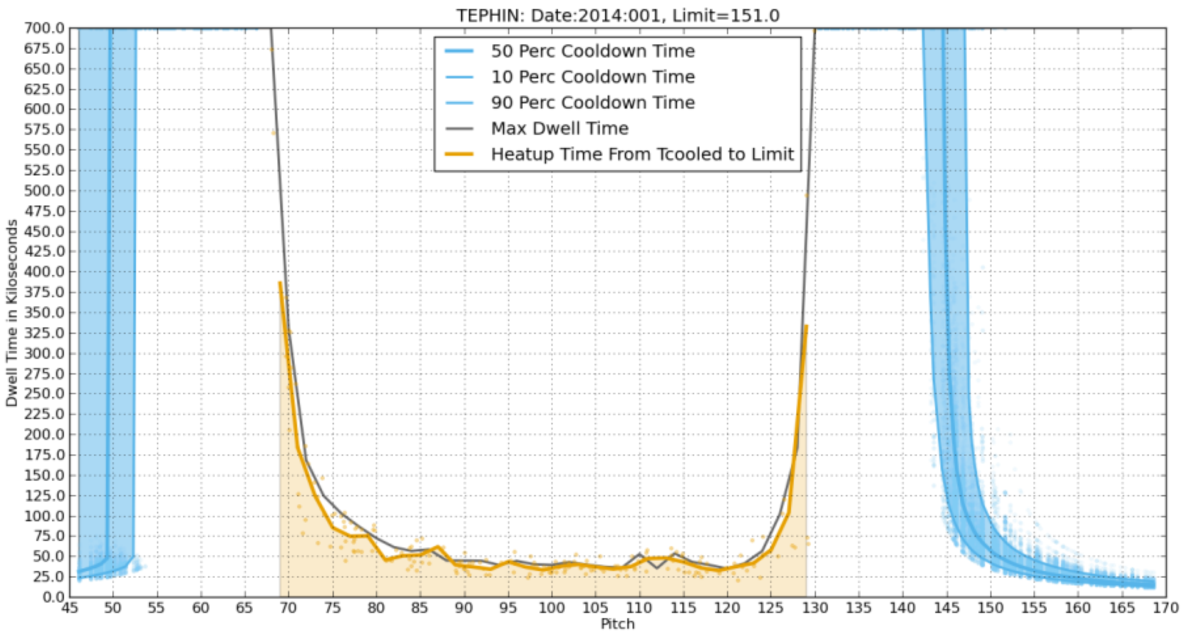
Spacecraft Status - Radiation Detection

- ACIS and HRC now provide on-board radiation monitoring
- Upcoming FSW patch will logically remove EPHIN from the radiation detection logic due to performance issues at hot temperatures
- EPHIN H&S no longer driver for EPHIN limit
- Phased relaxation will continue to prevent sudden change in maximum temperatures for units protected by the EPHIN constraint

No longer think about the “TEPHIN Limit”

Now more appropriately considered to be the “–Z Hardware Limit”

The phased relaxation is unlikely to eliminate this constraint all together



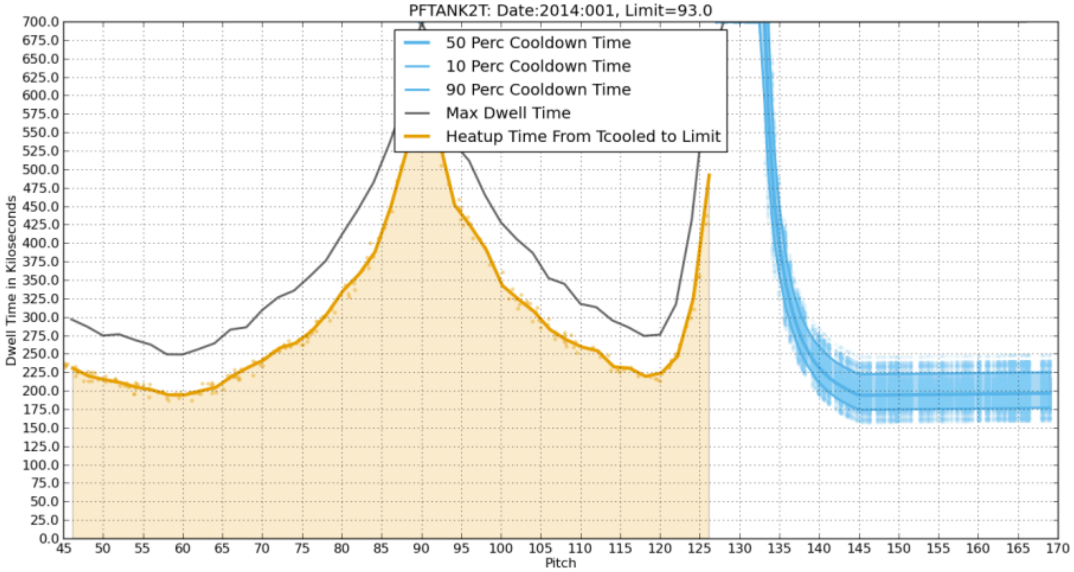
Spacecraft Status – Fuel Tank

- IPS tank temperature increases with time spent forward or mid sun
- No reliable test data exists for this type of tank at the temperatures we would see without enforcing temperature restrictions
- A test to lower the heater set-points for the tank to try to gain more observing time at cool temperatures was unsuccessful – the tank does not get cold enough
- Efforts underway to define a test program that would allow raising the temperature limit for the tank
  - Questions as to whether the results will be sufficiently convincing to allow a relaxation

The tank only came off heater control relatively recently

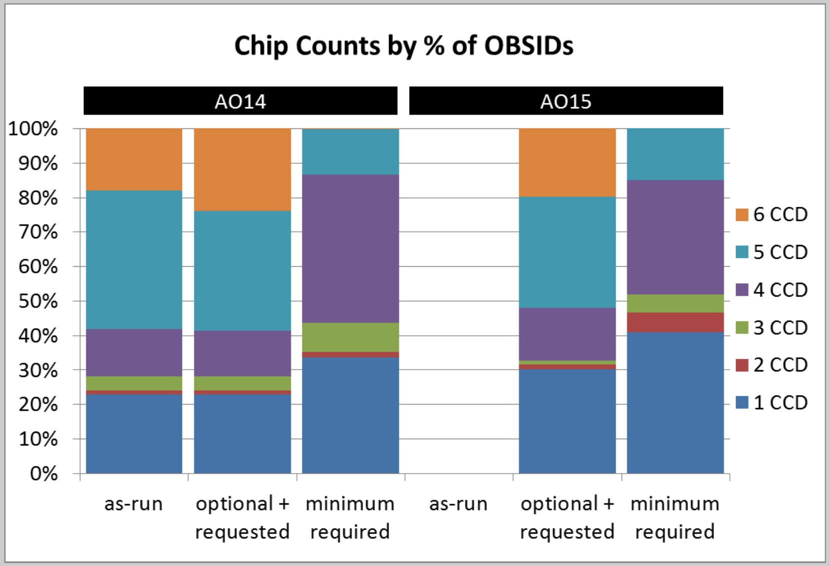
Defining the year-to-year expected rise in temperature is still a work in progress

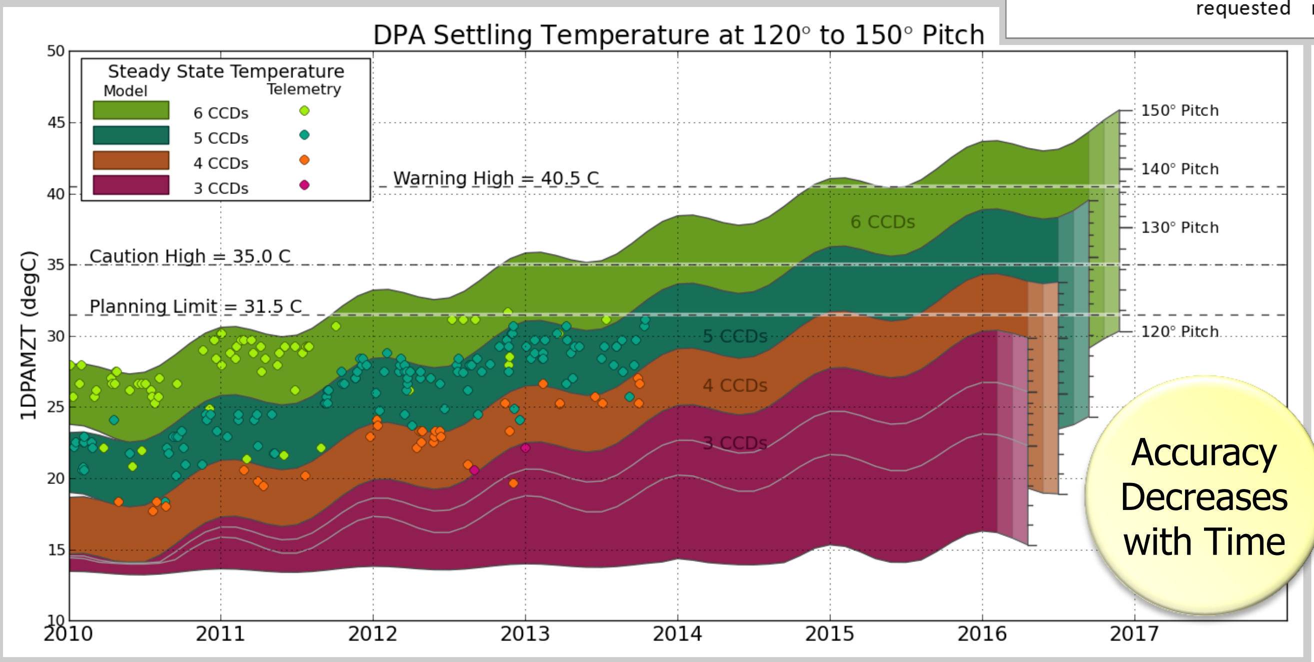
Current trends indicate that, when combined with other constraints, the tank has the potential to restrict observing capability in the near term



Spacecraft Status - ACIS DPA Heating

- ACIS DPA tested 40.5° C
- Contributors to DPA heating are
  - Tail sun attitude
  - Number of chips clocking
- LTS layout works to avoid placing observations with 5+ chips at tail-sun
- Optional chips dropped when necessary to prevent splitting observations





Pursuing planning limit increase to 33° C to take advantage of increased confidence in the predictive thermal model

Spacecraft Status – ACIS FP Temperature

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- ACIS Focal Plane cannot always be maintained at the -119.7 ° C when
  - Pitch angle >120 and 5+ chips
  - Earth in Radiator FOV (only at low altitudes)

Observations

All ACIS observations benefit from cold and stable FP temperature, though not all require -119.7C

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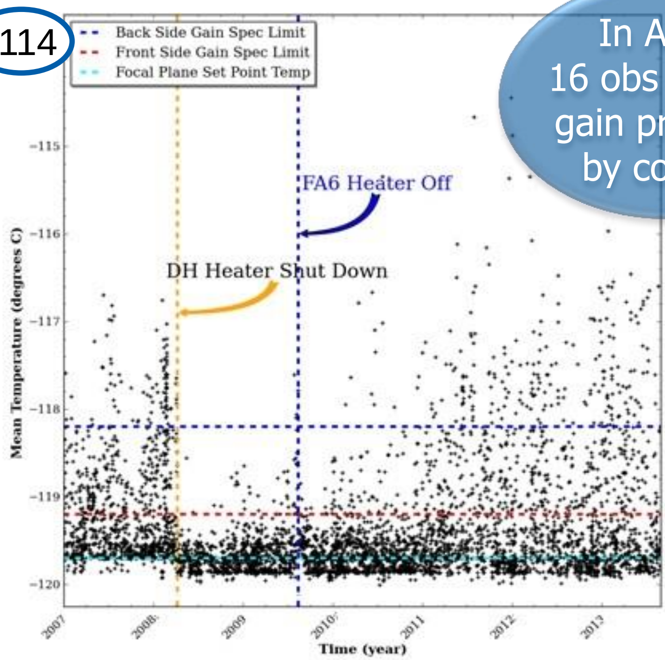

In AO15
16 obs require
gain provided
by cold FP

ECS Measurements (aka CTIs)

Only ECS measurements with a cold and stable FP temp can be used to calibrate performance at -119.7 C

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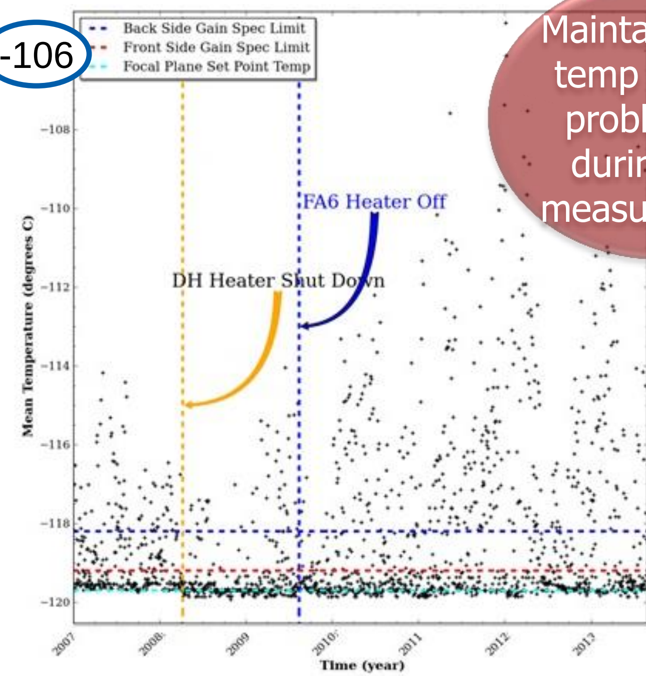
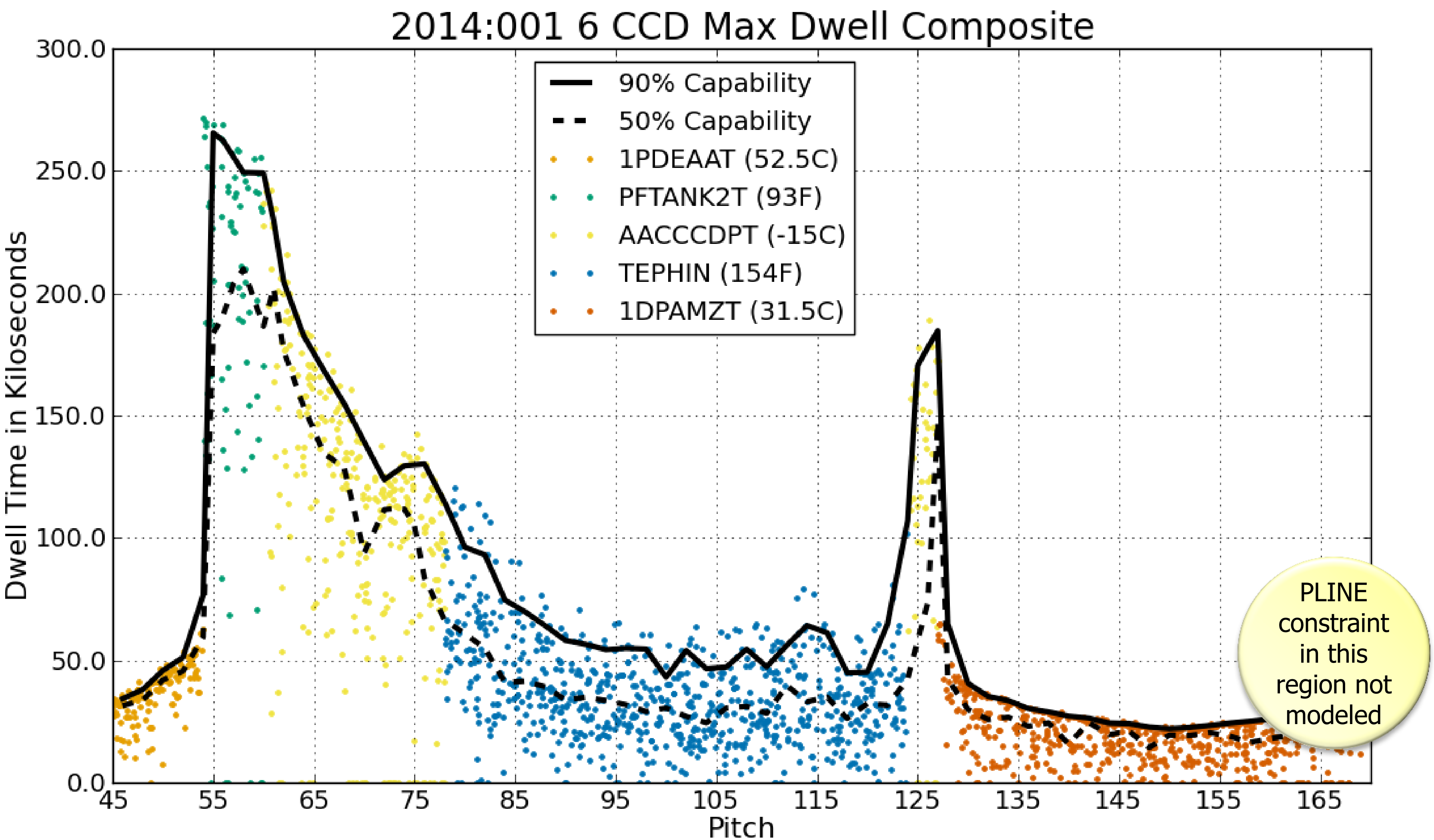
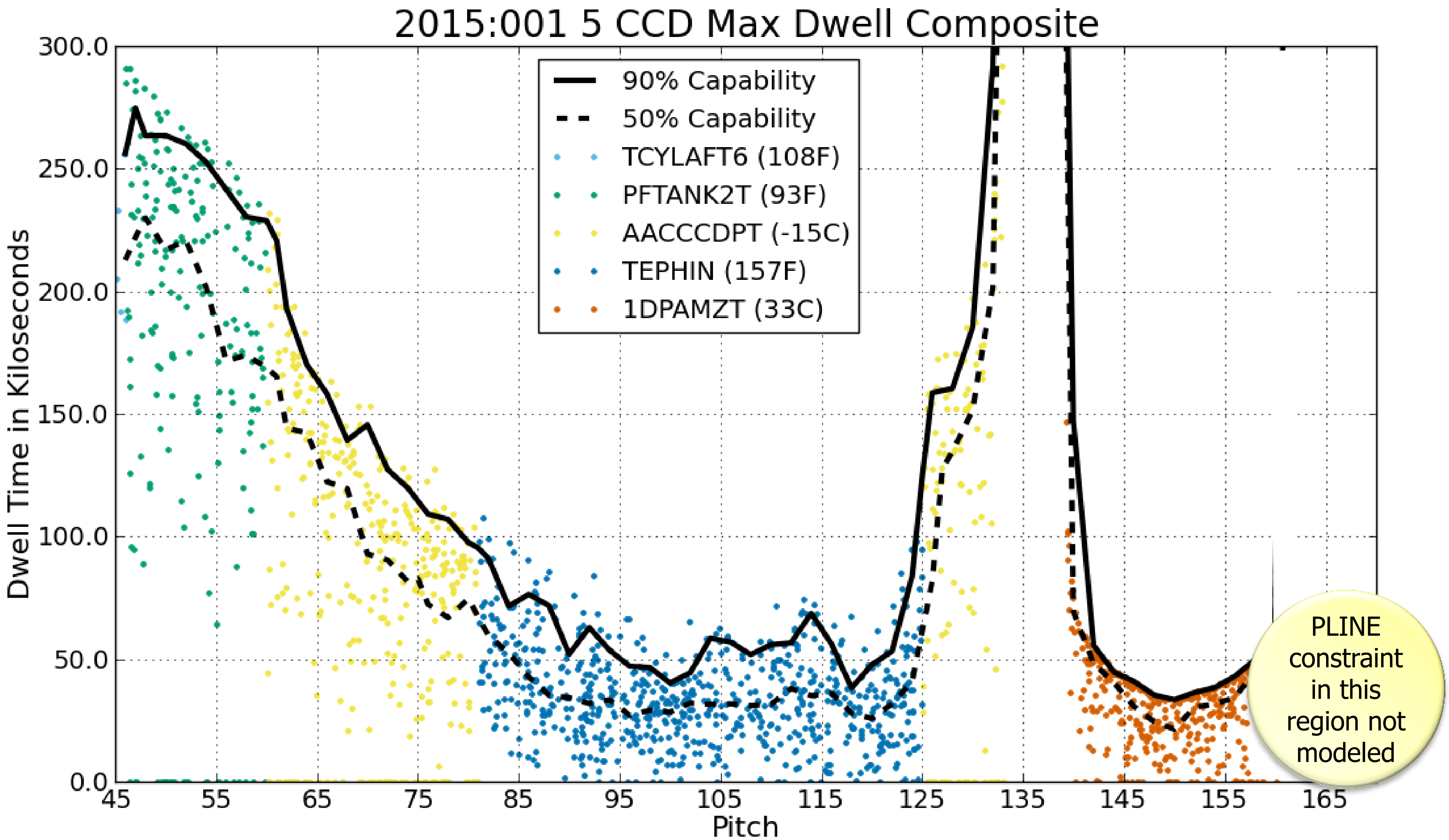


Maintaining FP
temp is most
problematic
during ECS
measurements

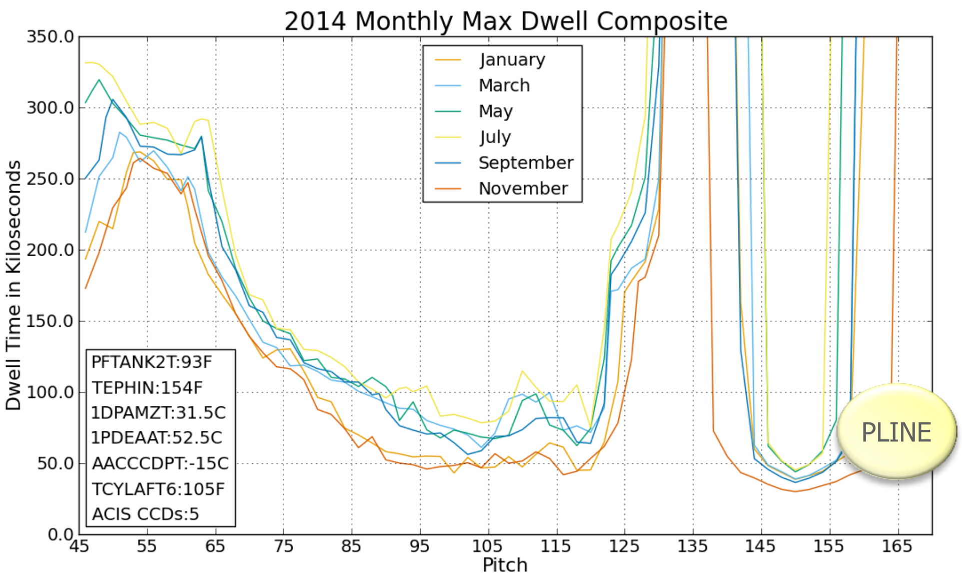
Thermal Constraint Composite

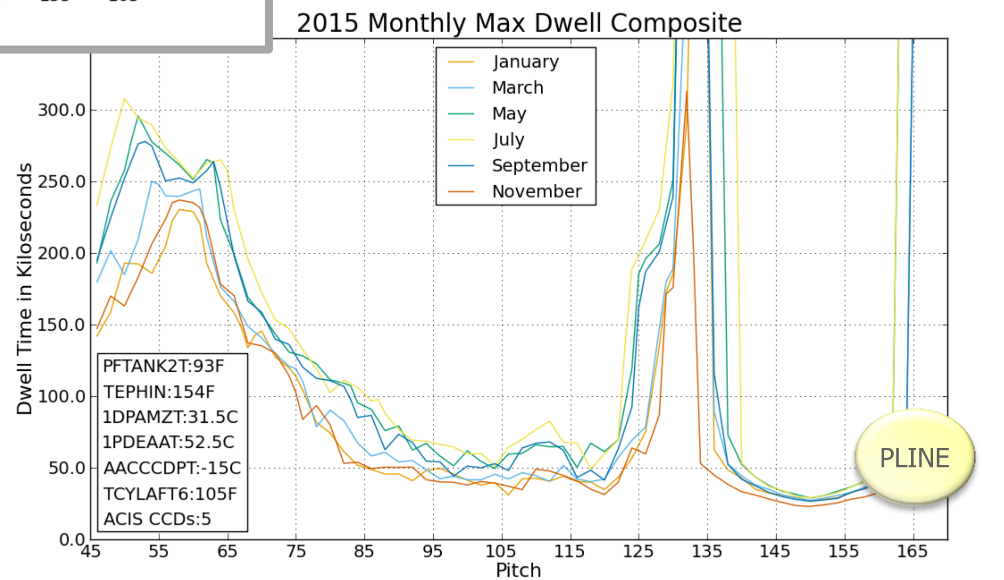


Thermal Constraint Composite



Seasonal Variation in Dwell Times

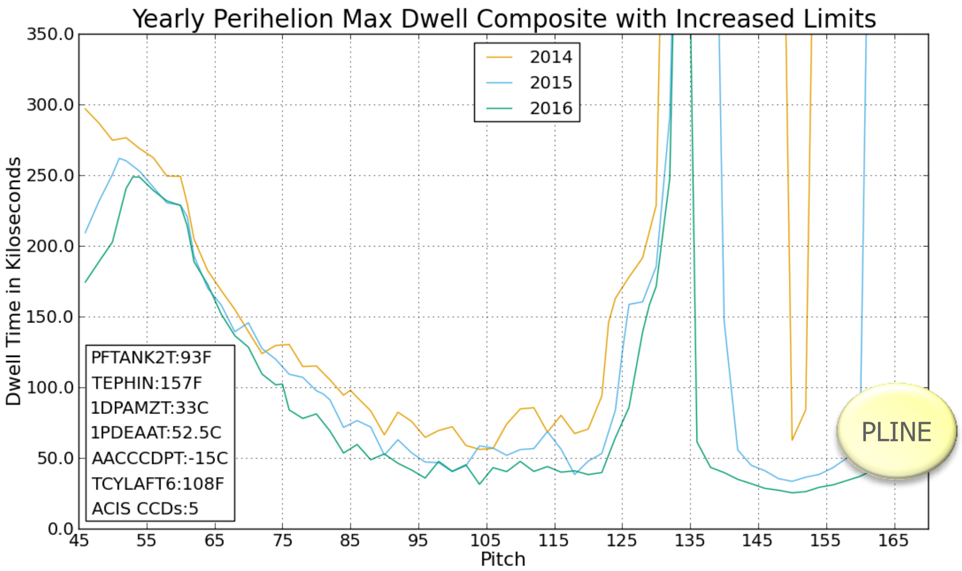




Dwell time capability impacted by seasonal variation

Shortest available dwells during hot season (centered around January)

Predicted Dwell Times



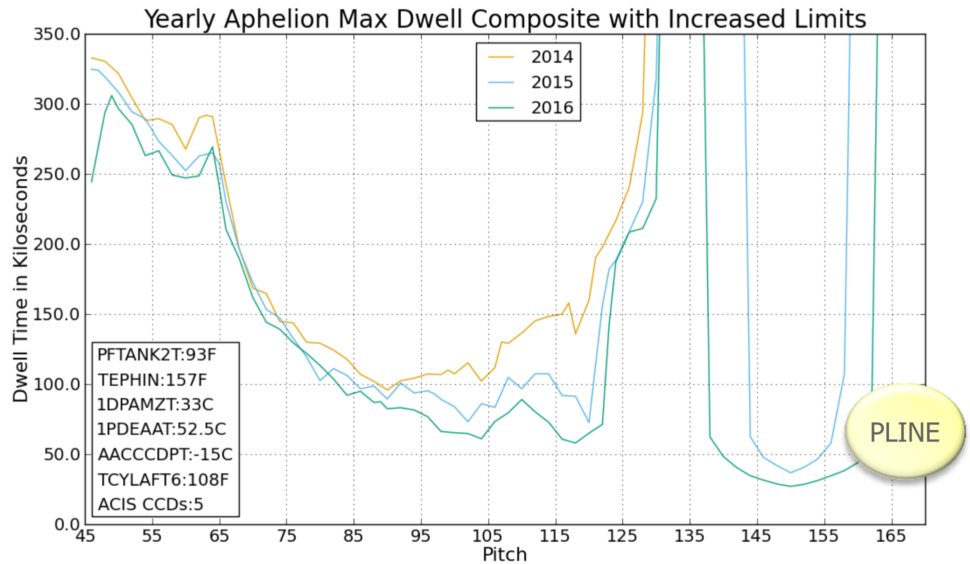
Limit increases for some components (-Z Hardware and TCYLAFT6) are expected as long as no safety or performance issues emerge

Anticipate scheduling challenges with competing DPA, EPHIN, IPS tank, ACA constraints

Very difficult to predict long-term dwell capability

Year-to-year temperature increases not following expected curves

Relaxations in one area often reveal needed constraints in another

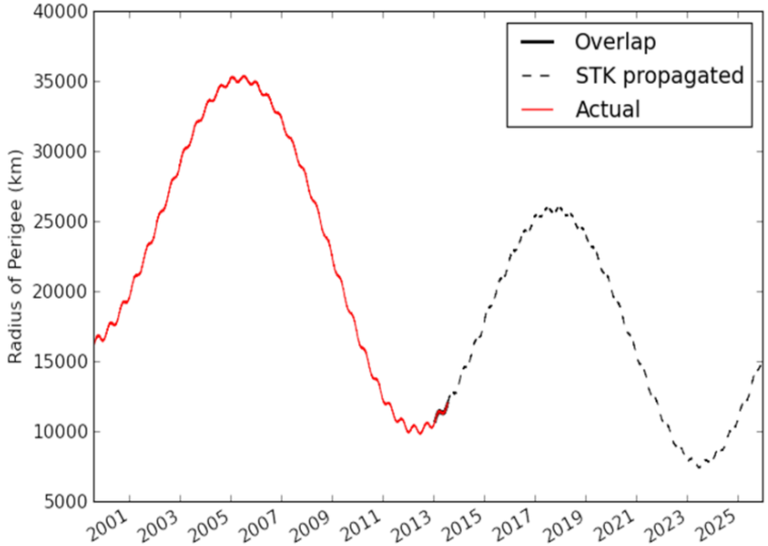


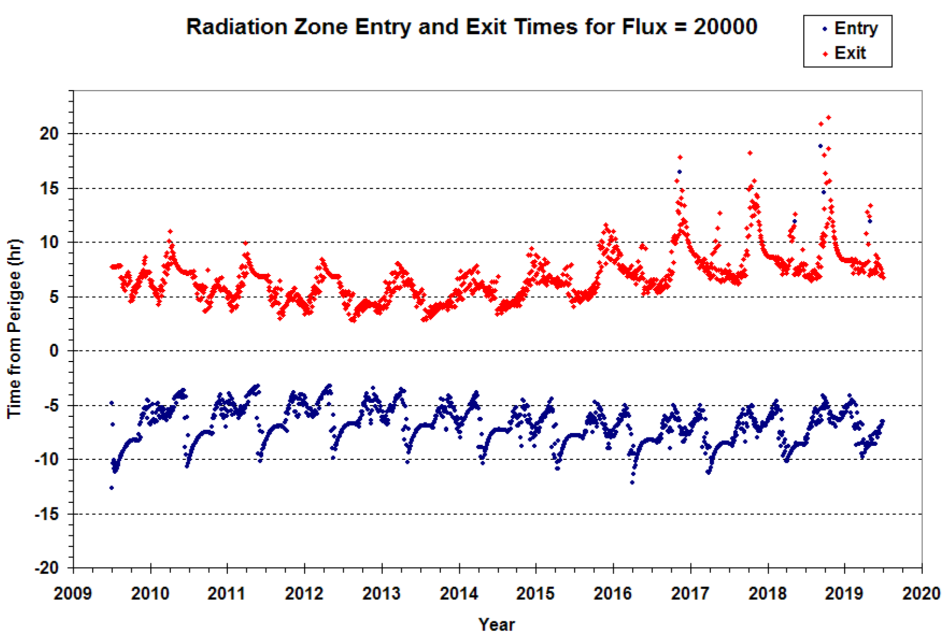
Orbit Changes

With no adjust capability, Chandra's orbit will continue to evolve

We are currently circularizing, but it will turn around in 2017

Chandra will face another low perigee in 2023, lower than in 2012





With the low perigee of 2012 radiation zone passages shortened

Wall-clock efficiency has been at mission highs due to an increase in available time

The radiation zones are increasing in duration again, so available time is decreasing toward historical norms

Summary

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- In general, the Chandra Spacecraft continues to be in excellent health
- Recently emerging issues do present some challenges
  - Degradation of thruster A1 and failure of thruster B2 will present challenges with momentum unloading and reduce our options for managing additional failures within the propulsion subsystem
  - FSS-A concerns have been addressed and do not impact mission capability
  - ACA beginning to show performance impacts due (largely) to increased temperature, will be managed through a thermal constraint
- The biggest challenge going forward is managing the impact of conflicting constraints
  - Attitudes that are cool for ACIS are hot for spacecraft components
  - Newer constraints (ACA, Tank) impact large areas
  - Limits will be relaxed as possible, but we must proceed with caution
  - Thermal surface degradation is not well understood and we are constantly in new territory, so we must plan as carefully as we can, but be prepared for surprises
  - LTS planning will continue to be critical to success and we are focused on improving the tools available to aid in the layout process

Despite these challenges, the outlook for a continued successful Chandra mission is excellent