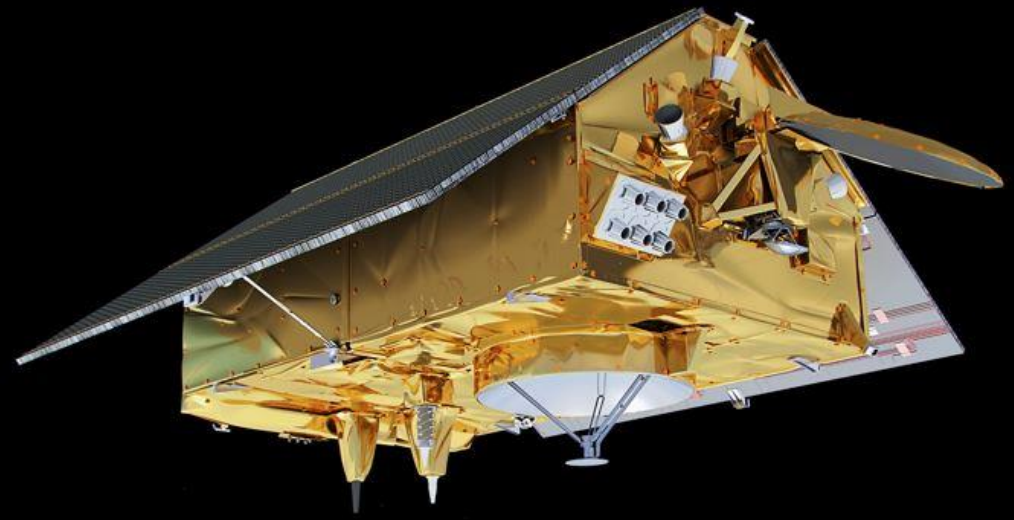
Sentinel-6 Project

Final Report



Internship 2017

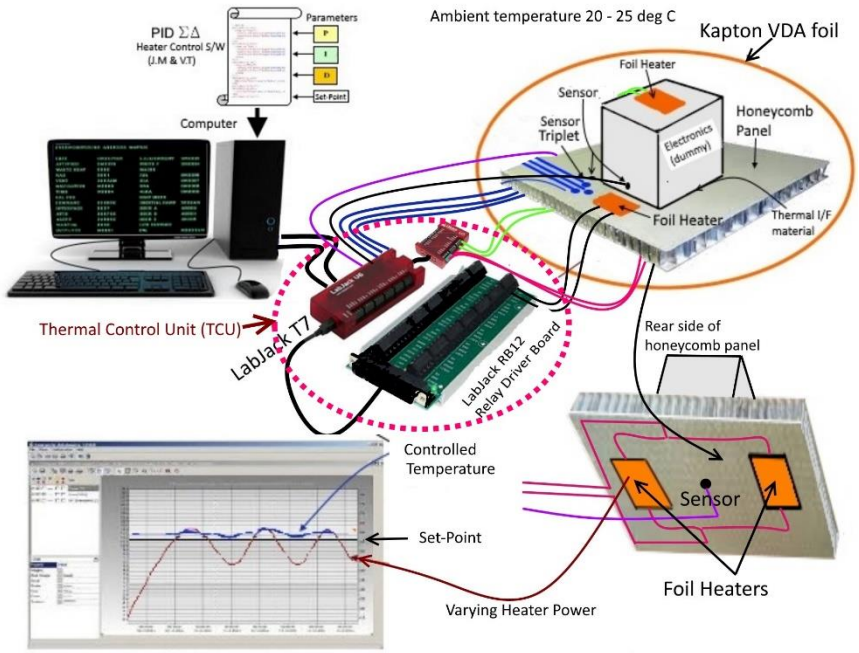
At Jet Propulsion Laboratory, California Institute of Technology

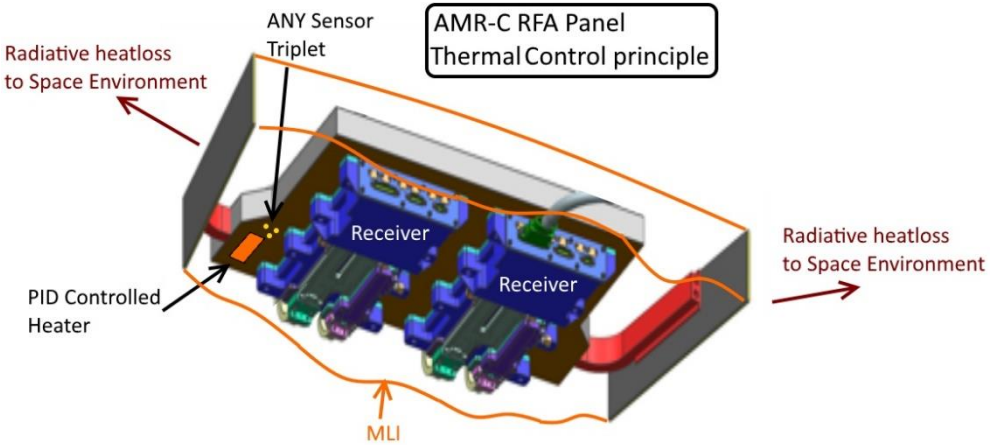
AMR-C Temperature Control

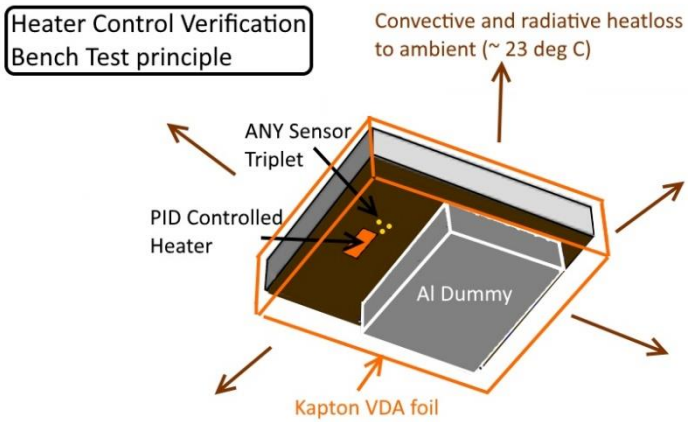
Benito Pimienta, University of Arizona

System Overview

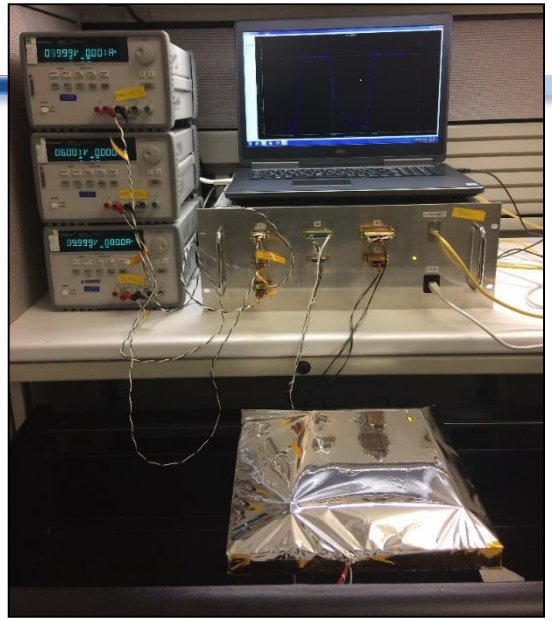
- Process
  - Hardware and Software Setup
  - Thermal Model Correlation/Validation
  - Prediction of PI parameters with correlated thermal model
  - Extensive PI testing



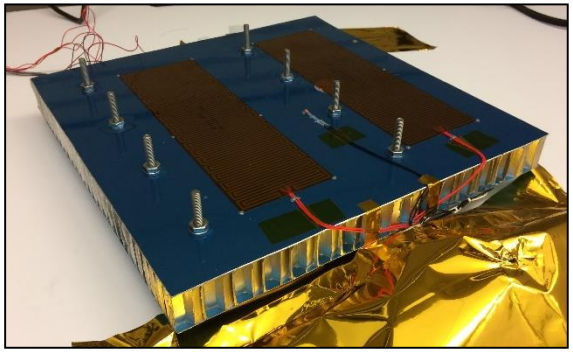


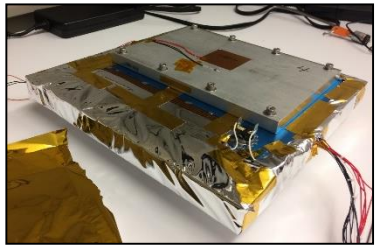


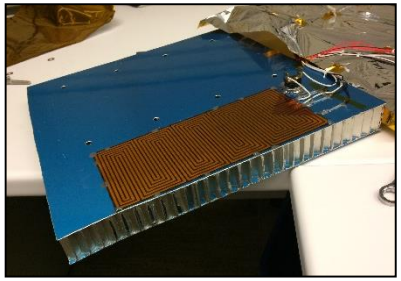
Hardware

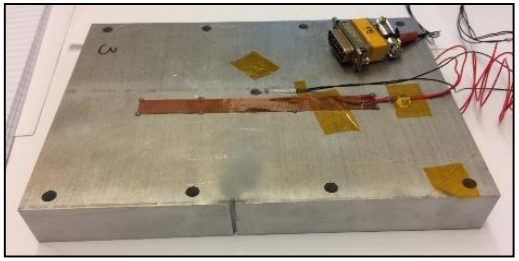


- Thermal Control Unit (TCU)
  - LabJack DAQ and relays
  - Interfaces with computer
- Honeycomb:
  - PI Control Heater Bonded to top side (HC HTR)
    - 12.6Ω Single Kapton Foil Heater
    - Thermistor Triplet (10KΩ-25C)
  - Disturbance Heater Bonded to back side HCRSW HTR)
    - Two 30.5Ω Kapton Foil Heaters in parallel
    - Single Thermistor (10KΩ-25C)
- High Thermal Mass Dummy Electronics (DEL1)
  - 79.9Ω Single Kapton Foil Disturbance Heater
  - Single Thermistor (10KΩ-25C)
  - 2.32Kg
- Low Thermal Mass Dummy Electronics (DEL2)
  - 122 Ω Single Kapton Foil Disturbance Heater
  - Single Thermistor (10KΩ-25C)
  - 1.15Kg



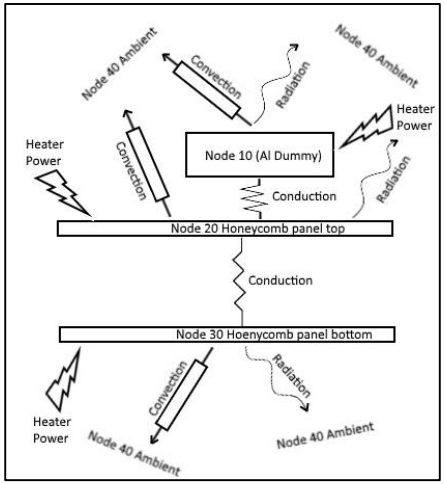






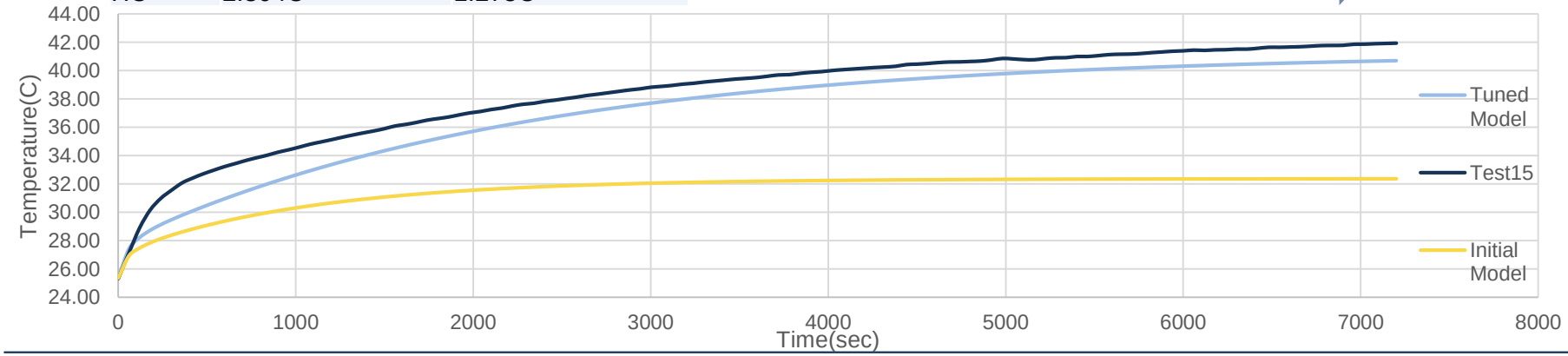
Thermal Model Validation

- Thermal Model created before testing; some critical parameters unknown
- 13 Tuning Tests
  - 9 Steady State:
    - Determine Steady State Power for temperatures of 30C, 40C
  - 4 Transient:
    - 3 heating and 1 cooling

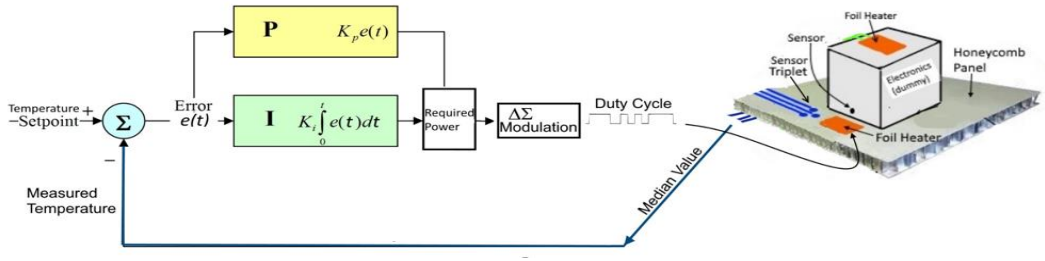


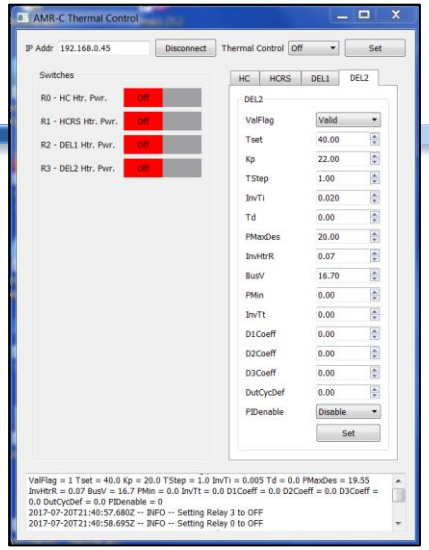
	Initial Model Temp. Diff.	Tuned Model Temp. Diff.
DEL2	2.805C	.343C
HCRS	2.905C	.691C
HC	2.804C	1.275C

Contact conduction dummy	Hc	100	W/m^2K	→	85	W/m^2K
Conduction through core	Hcore	54.5	W/m^2K	→	70	W/m^2K
Convective Heat Transfer	Hconvec	10	W/m^2K	→	4	W/m^2K
Cp		910	J(K-Kg)	→	910	J(K-Kg)

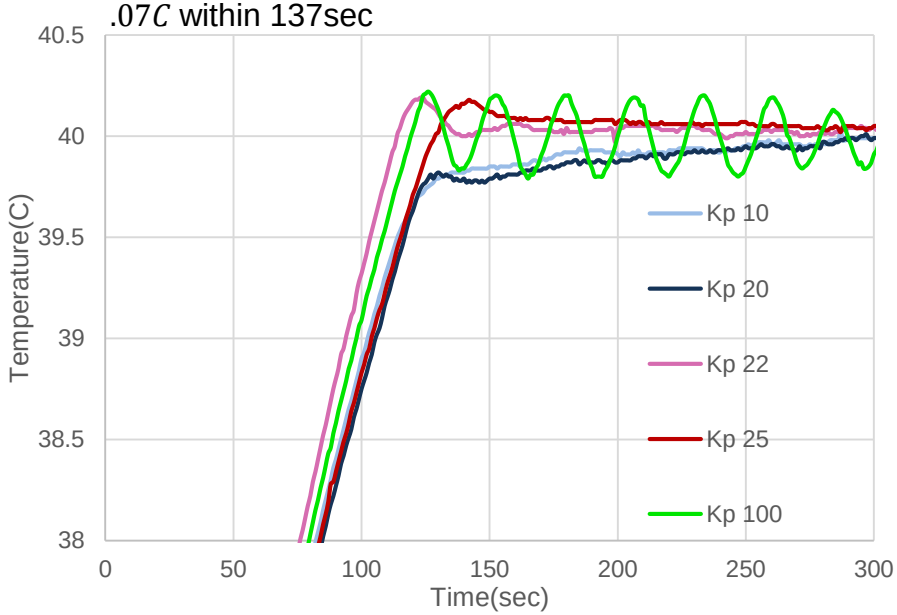


PI Tuning

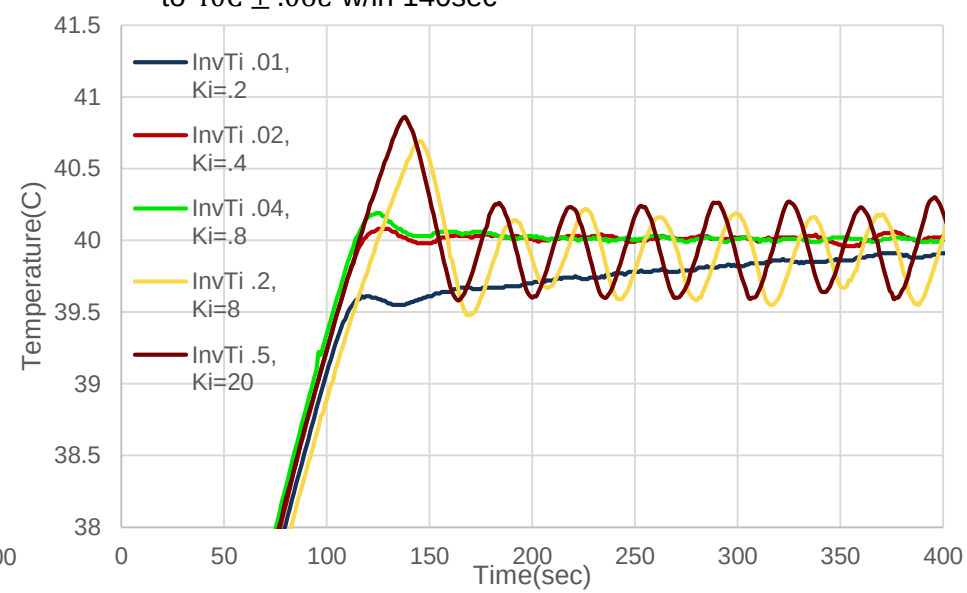




- 9 tests to tune Kp
  - Varied between 10 and 100
  - Kp>40: Unstable, oscillated
  - Kp<20: Decreased response time
  - Ideal Kp=22: .17C overshoot, settled to $40C \pm .07C$ within 137sec



- 8 tests to tune InvTi
  - Ki=InvTi*Kp
  - Varied between .01 and .5
  - InvTi<.01: Long response time, permanent offset
  - InvTi>.1: Quick response but large overshoot and unstable
  - .04>InvTi>.02: rose to 40C w/in 2min, .2C overshoot, settled to $40C \pm .06C$ w/in 140sec

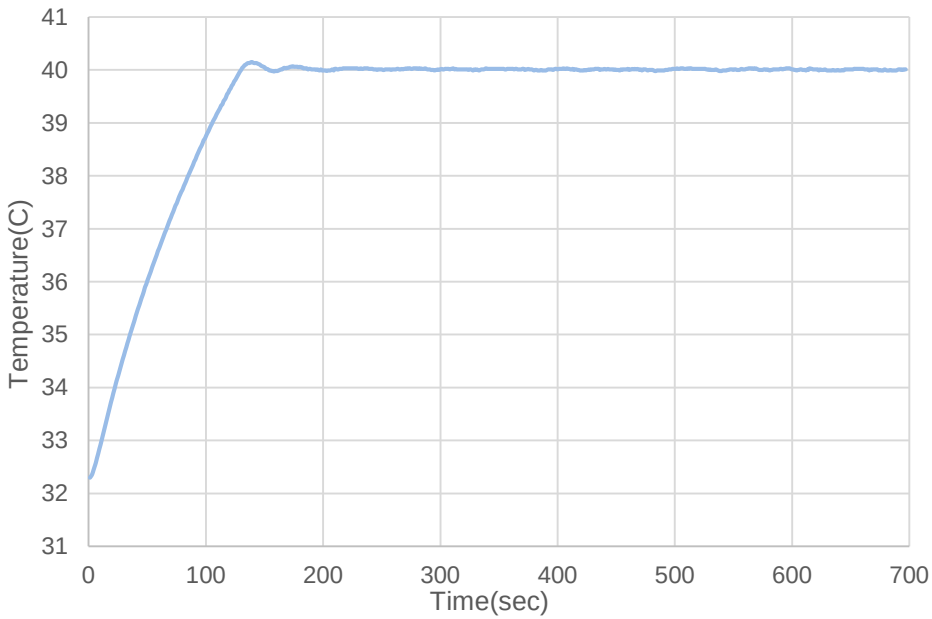


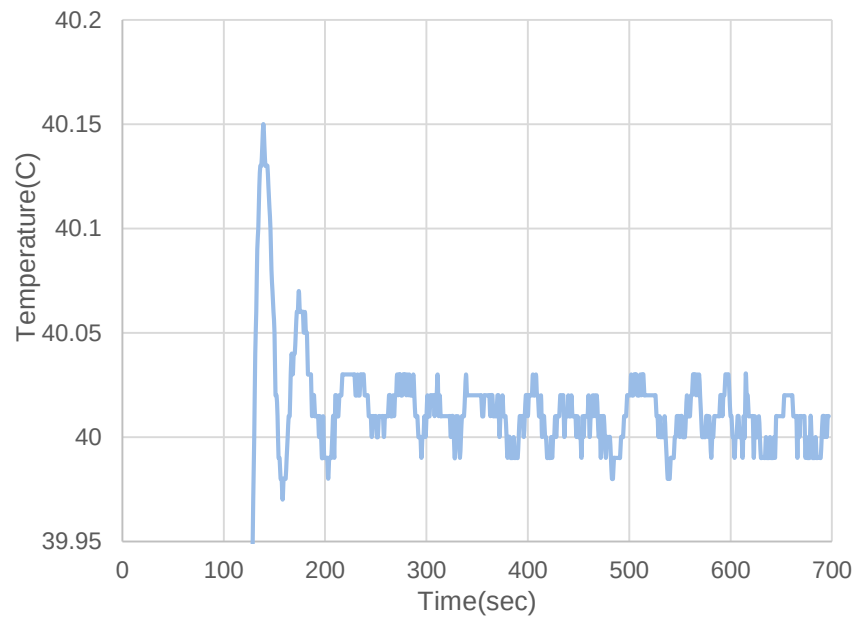
PI Tuning

- Optimized Parameters
  - Kp=22
  - InvTi=.02

ValFlag	Tset	Kp	Tstep	InvTi	Td	PmaxDes	InvHtR	BusV	Pmin	InvTt	D1	D2	D3	DutCycCef
Valid	40	22	1	.02	0	20	0.07	16.7	0	0	0	0	0	0

- Test Characteristics
  - Reaches Tset=40C in 130sec
  - .15C Overshoot
  - Settles to $40C \pm .06C$ within 17sec
  - At steady state $40C \pm .02C$

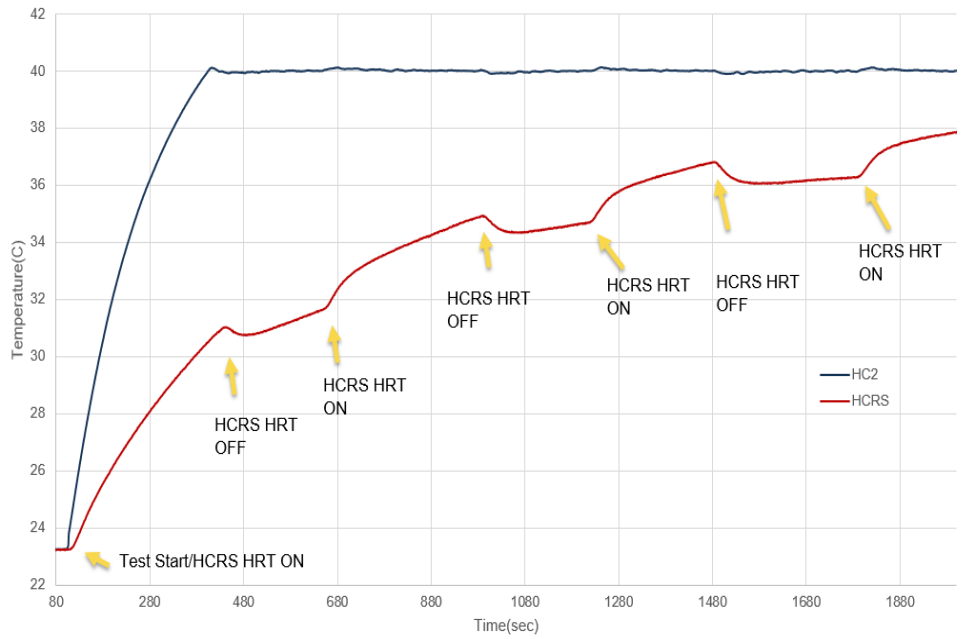


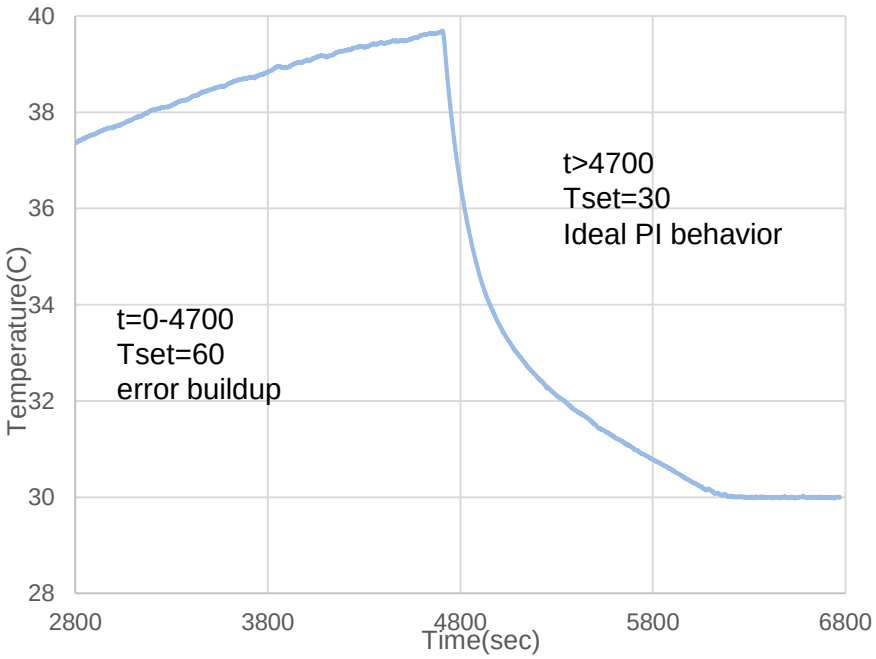


PI Testing Cont.

- Disturbance heaters used to determine if PI controller could compensate for increase in power
- HCRS HRT set to 9W
  - Minimal time delay
  - Close to saturation
- Results
  - .12C Overshoot
  - Temp. Increased to 40.13C before PI could compensate
  - Temp. Decreased to 39.9C before PI could compensate
  - Settled to $40C \pm .05C$ within 190 seconds

- The PI algorithm has a built in feature to prevent Integral windup
  - Set InvTt=1 to activate back-calculating anti-windup logic





Acknowledgements/Questions

- I would like to thank Frank Maiwald and John Kanis for guiding me through this internship. Without their continued support, I would not have been able to accomplish what I did.
- I would like to thank the AMR-C team for welcoming me into the group.
- I would like to thank the Education Office for making this internship possible.