TFAWS Passive Thermal Paper Session

Modeling and Analysis of the Hurricane Imaging Radiometer (HIRAD)

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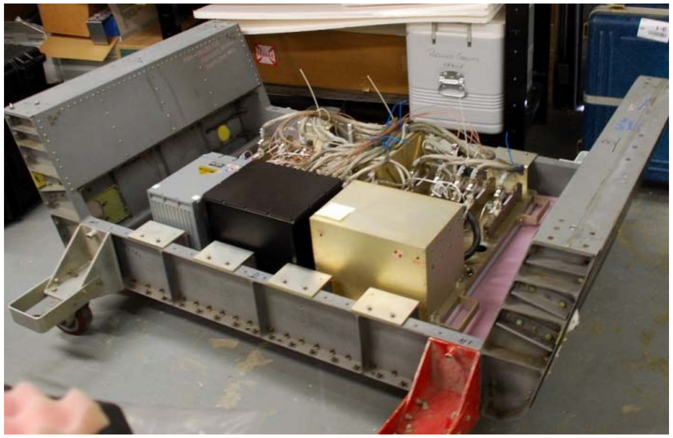
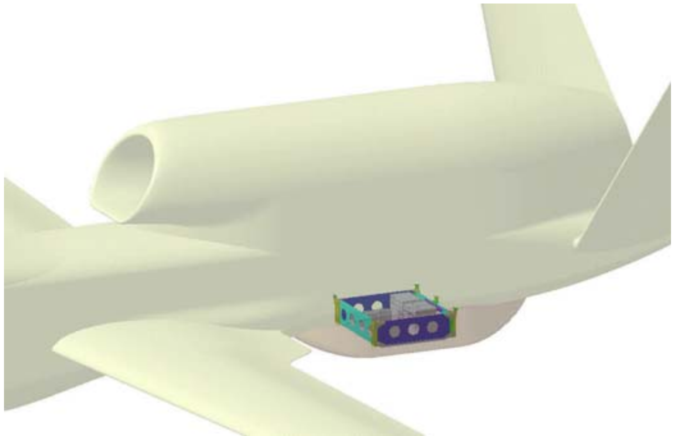
Outline

- HIRAD Overview
  - Components & Heat Dissipation
- 2012 Modeling and Analysis
  - Goals
  - Thermal Desktop Model & Analysis
  - Correlation to Experimental Data
  - Recommendations
- 2012 Season Flight Data
- 2013 Modeling and Analysis
  - Goals
  - Thermal Desktop Model Updates
  - Correlation to Flight Data
  - Environmental Chamber Testing
  - Recommendations
- Conclusions and Forward Work
- Lessons Learned

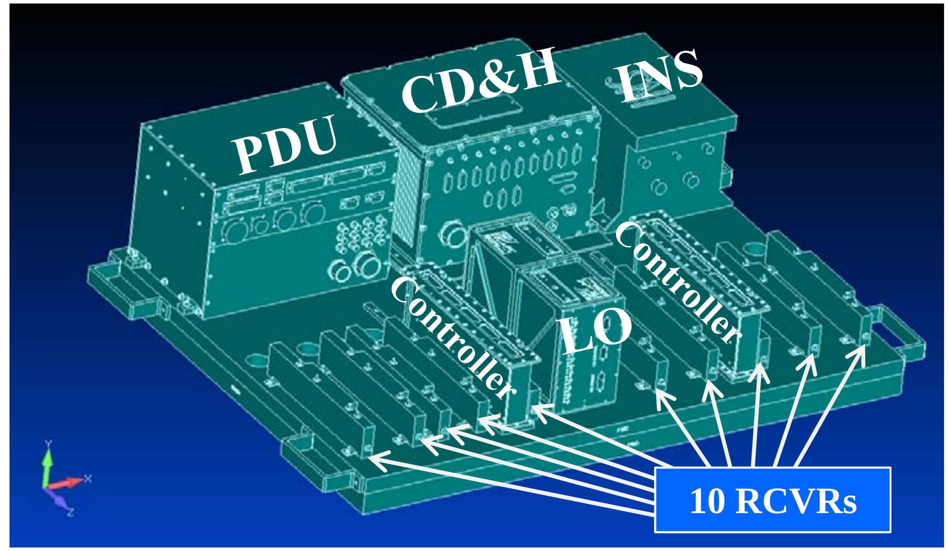
HIRAD Overview

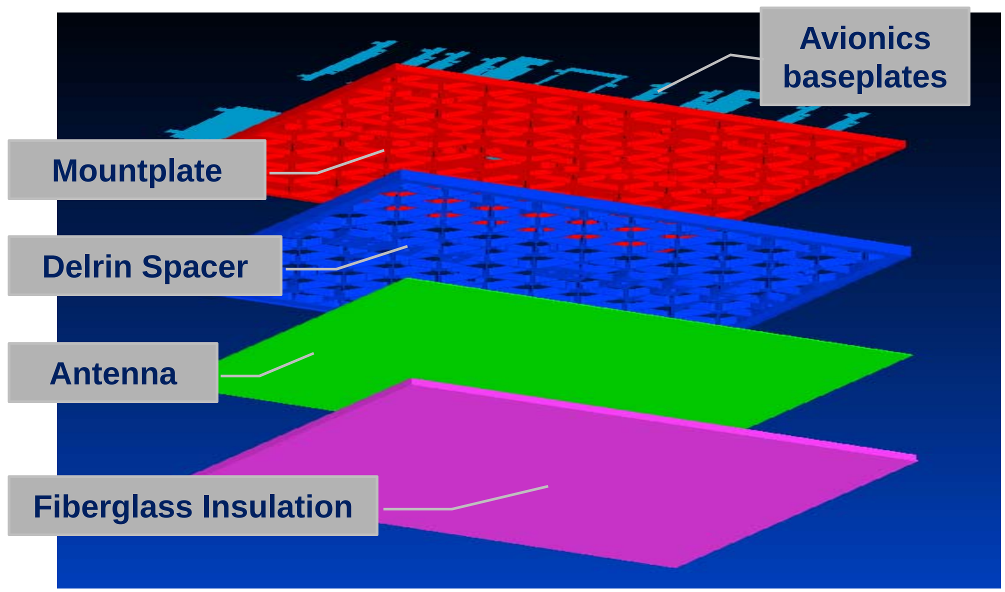
- Hurricane Imaging Radiometer
- Airborne sensor flown on UAVs through hurricanes
- Flown up to 60,000 ft.
- Purpose:
  - Produces a wide-swath image of ocean surface wind speed
  - Measures near surface rain rates

HIRAD Components

- Electronics affixed to mountplate:
  - Power Distribution Unit (PDU)
  - Command & Data Handing (C&DH)
  - Inertial Navigation System (INS)
  - Local Oscillator (LO)
  - Controllers (2)
  - Receivers (10)
- MLI blanket covers the receivers, controllers and LO
- Stack below mountplate:
  - Delrin Spacer
  - Antenna
  - Fiberglass Insulation

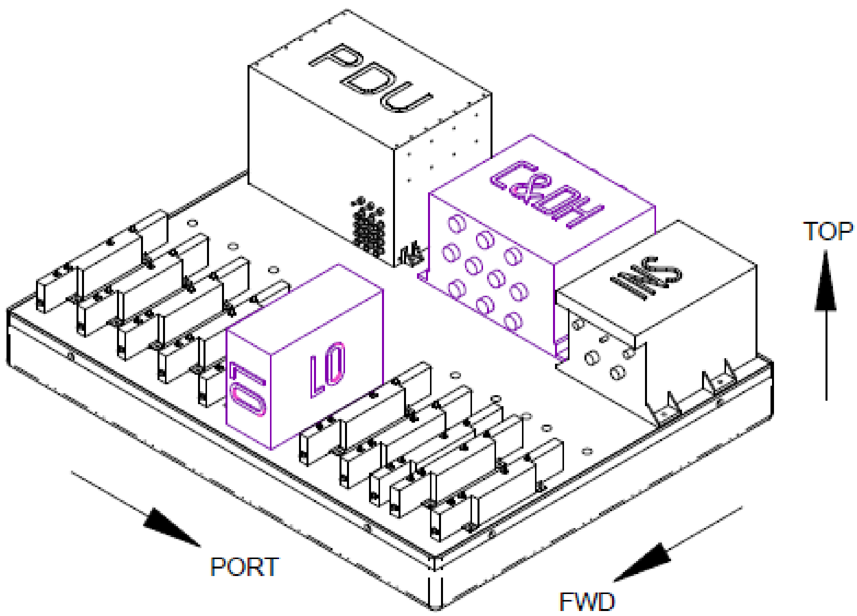




Heat Dissipation by Electronics Boxes

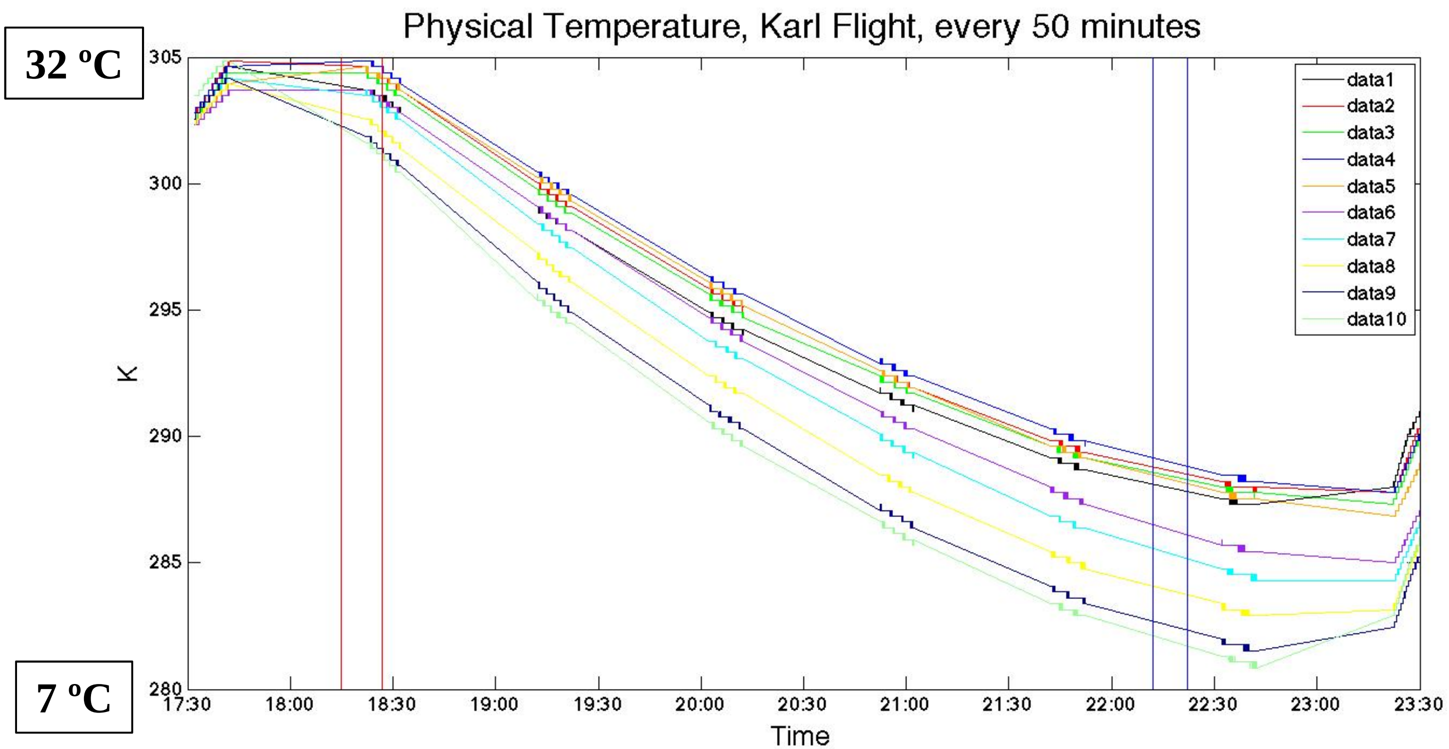
- All electronic components running at maximum power:

Component	Power [W]
Power Distribution Unit	128
Command & Data Handing	126
Inertial Navigation System	39
Local Oscillator	56
Receivers	4.5 each



2012 Thermal Modeling Goals

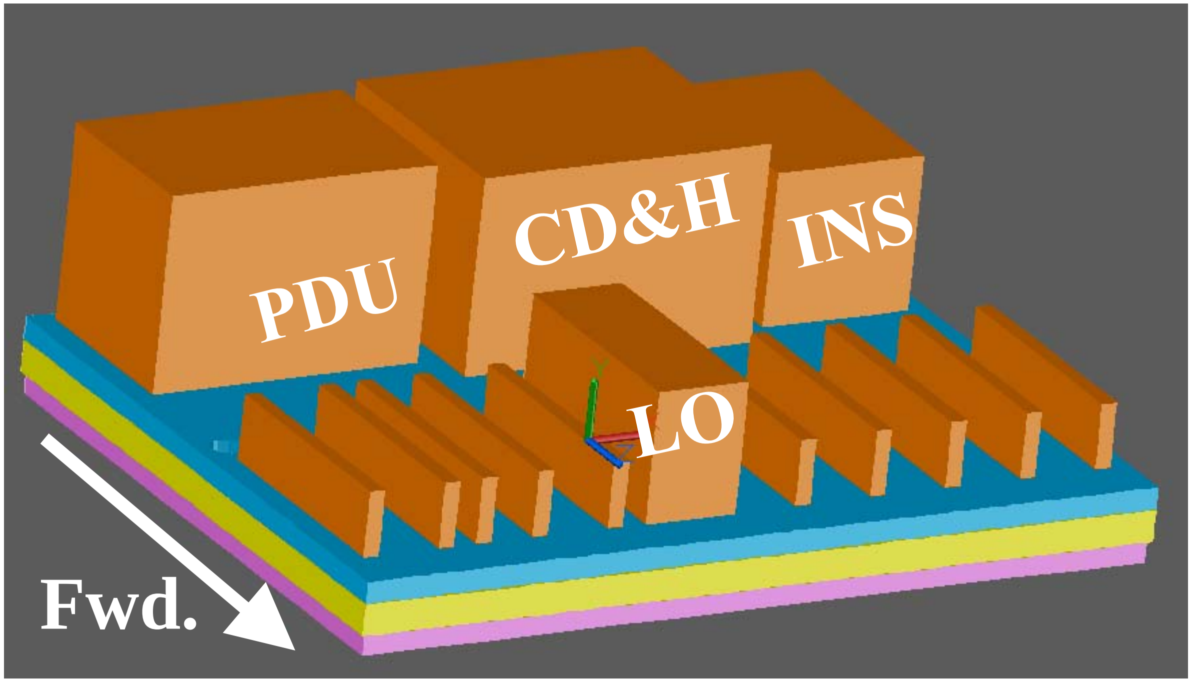
- Build representative thermal model
- Correlate receiver temperatures of model to minimal flight data from **2011 Season flight:**



- Recommend heater design to maintain steady receiver temperatures throughout flight

2012 Thermal Modeling Analysis

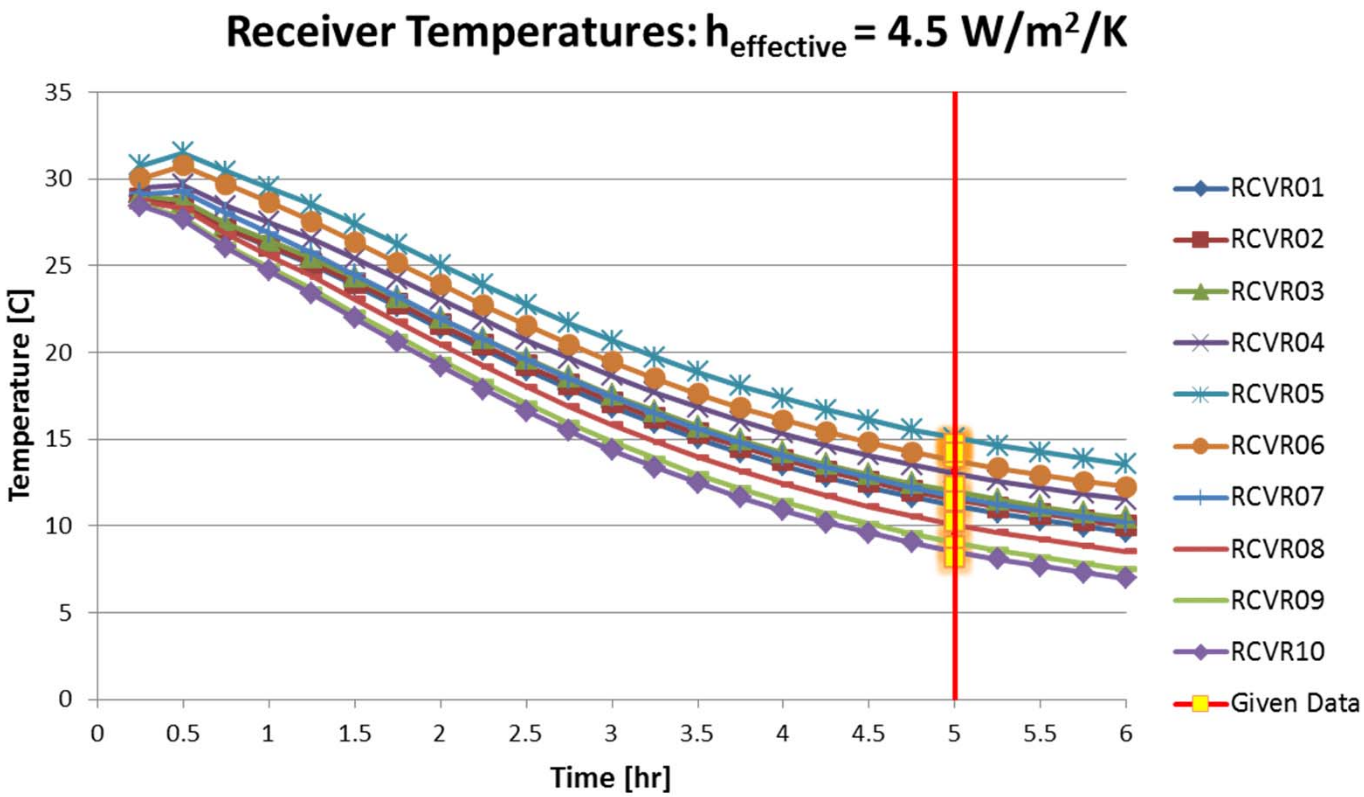
- Thermal Desktop Model view of modeled components:



- MLI blanket covering forward avionics boxes
- Effective heat loss from avionics components to boundary
- Transient boundary conditions:
  - 0 hrs: 31 ºC
  - 0.5 to 6 hrs: constant -60 ºC

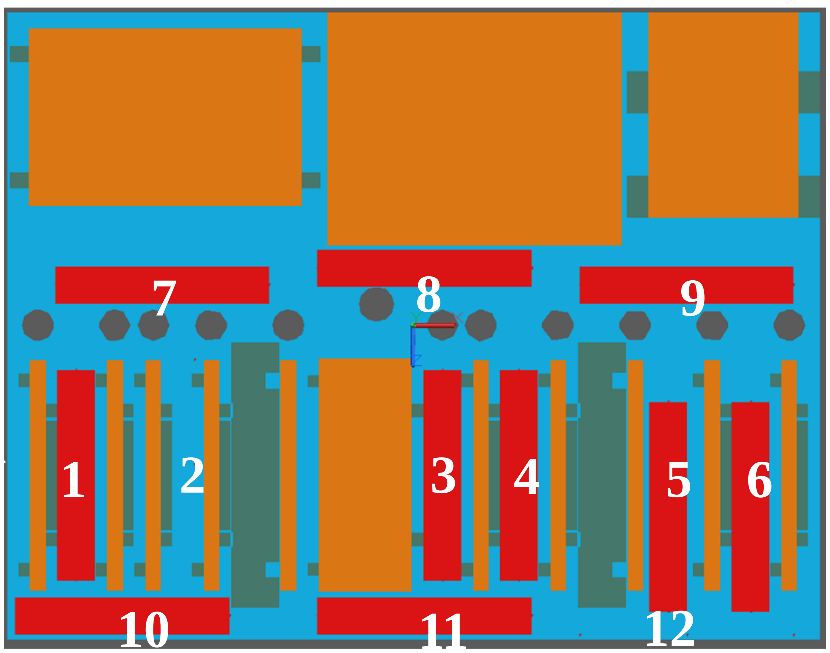
Receiver Temps of 2012 Correlated Model

- Transient Boundary Conditions
  - 0 hrs: 31 ºC
  - 0.5 to 6 hrs: constant -60 ºC
- Effective heat loss selected: $h_{effective} = 4.5\ W/m^2/K$

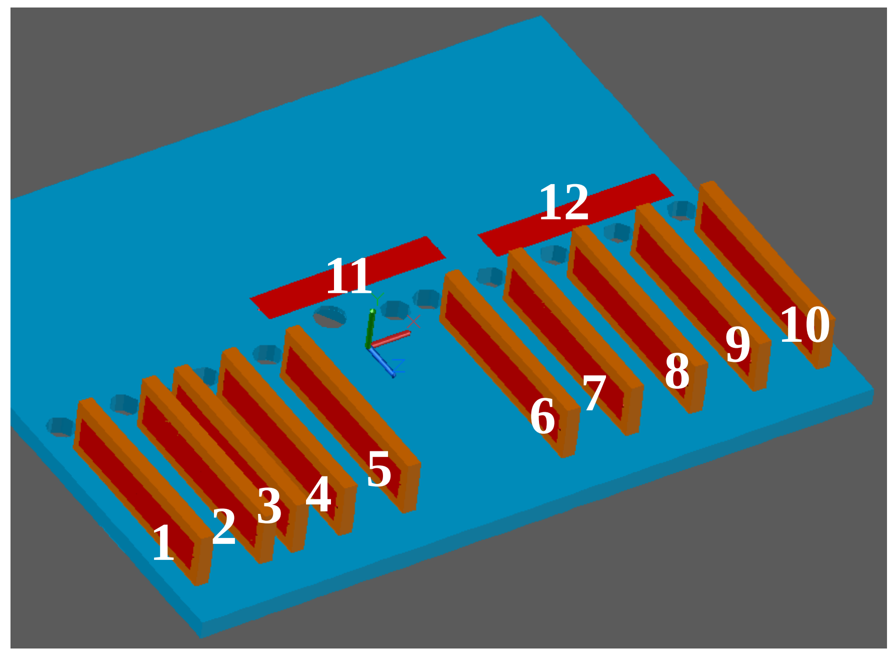


Heater Positions

- Birk Manufacturing flexible Kapton heaters
  - 1.75 x 10 in
  - 28 V, 28 W each
- Two different heater layouts investigated:
  - Heaters on mountplate
  - Heaters primarily on receivers



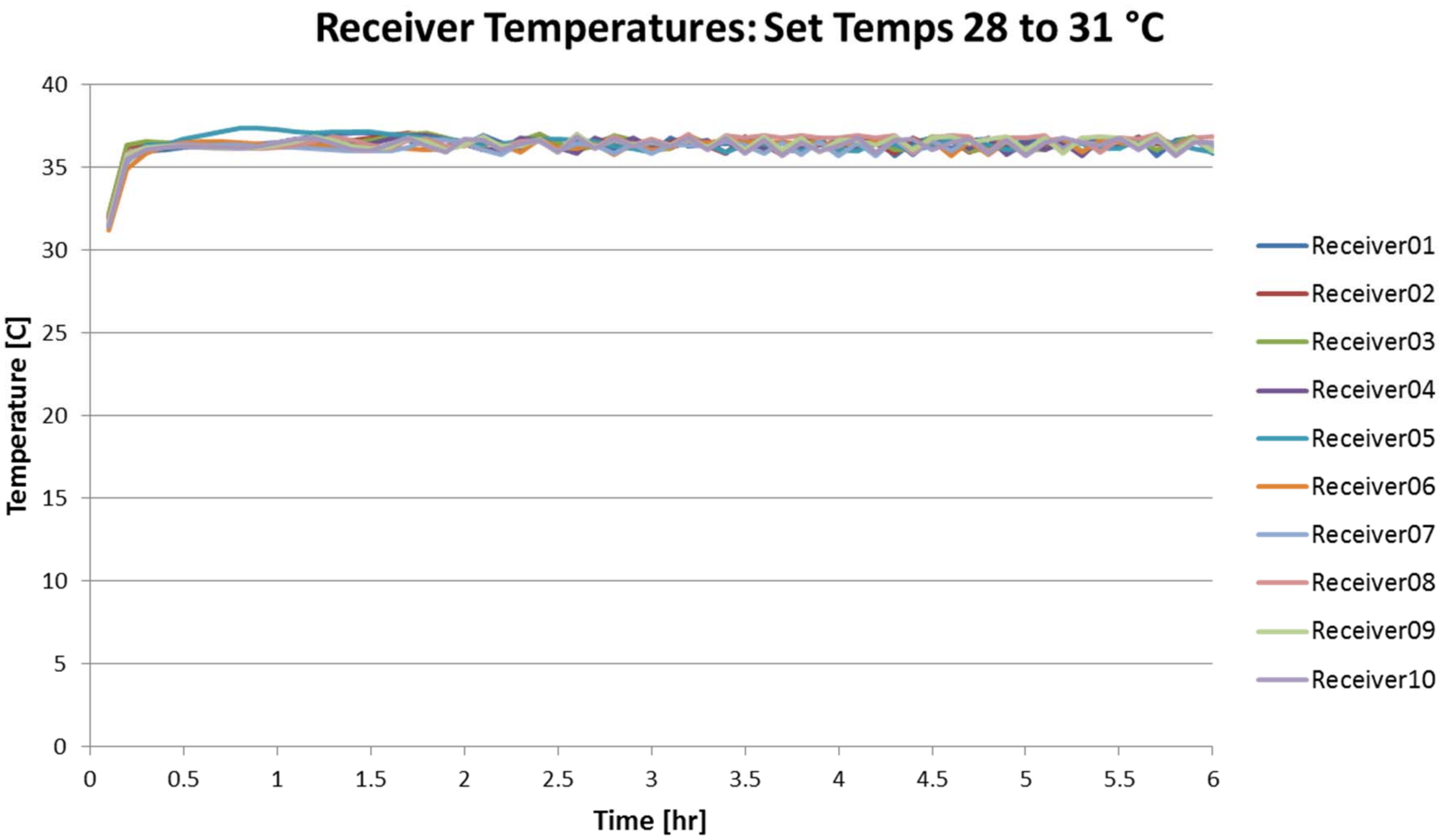
Layout 1: Heaters on Mountplate



Layout 2: Heaters on Receivers

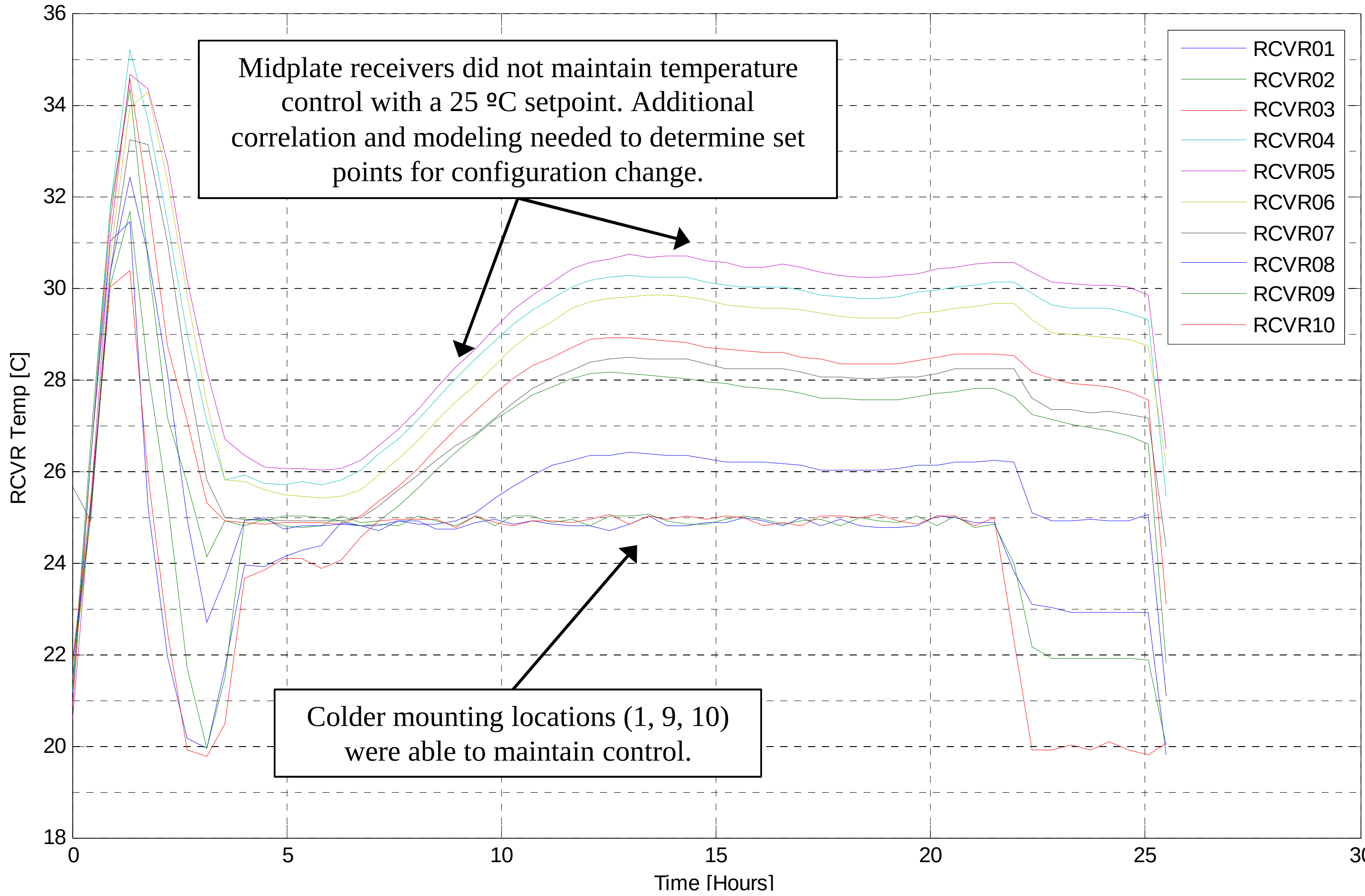
Recommendation based on 2012 Model

- Recommended placing heaters on the sides of each receiver to provide the least temperature variation from receiver to receiver
  - Set temperatures: 28 to 31 ºC recommended



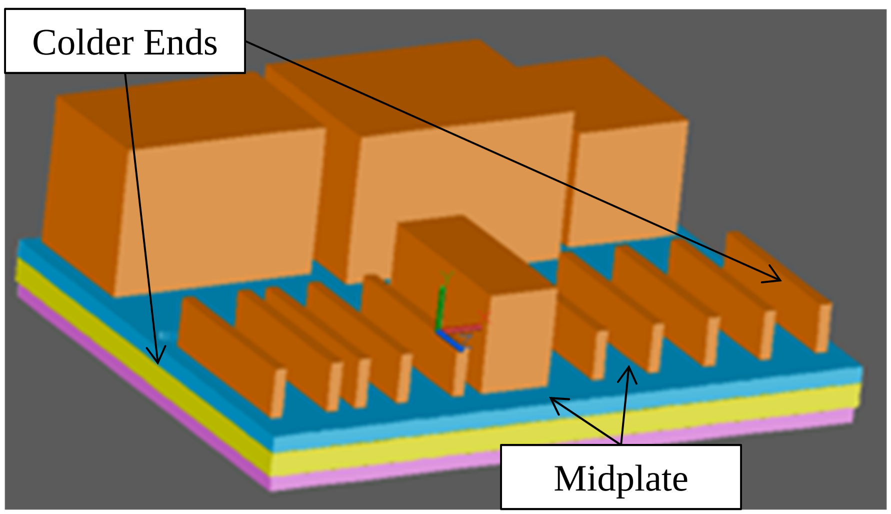
2012 Flight Data

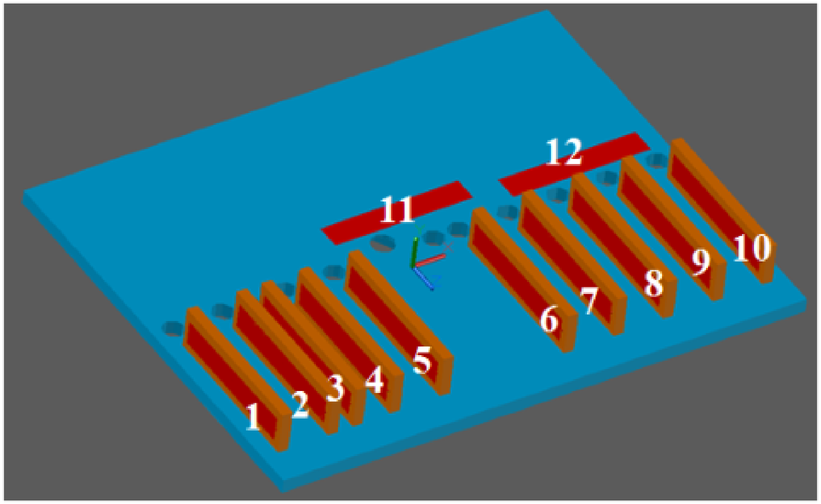
- Latest receiver temperatures recorded throughout Global Hawk flight using heaters on the side of each receiver with set point of 25 ºC



Conclusions based on 2012 Flight Data

- Midplate receivers reach higher temperatures than receivers on the end of the plate
- Brackets and Controllers (previously not modeled) contribute to thermal environment
- Each heater heats the receiver it is attached to through conduction and adjacent heaters through convection



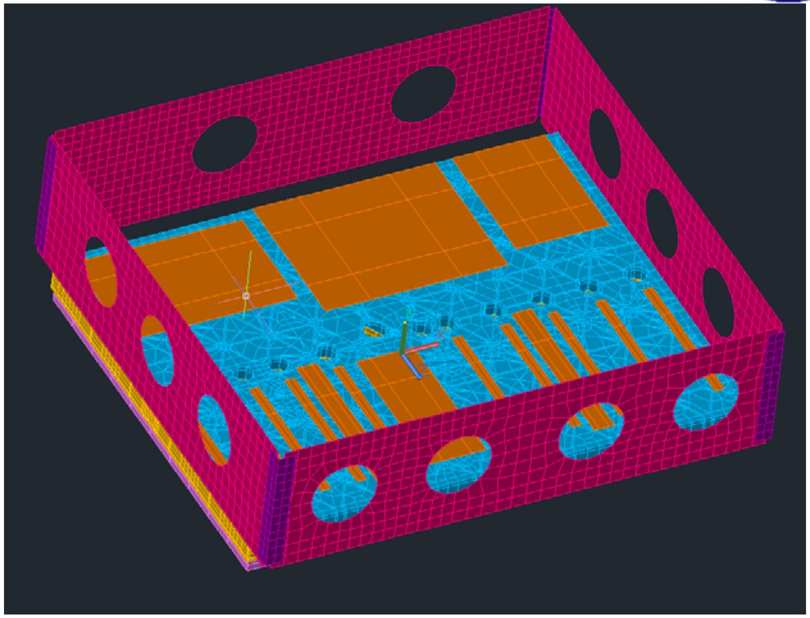


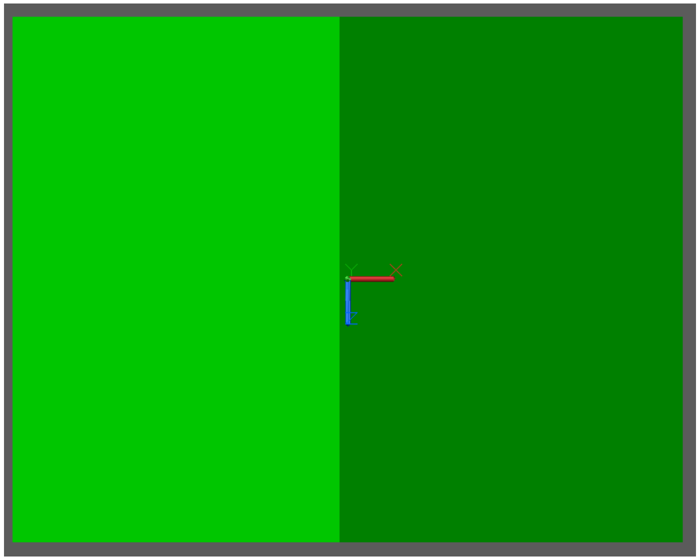
Forward Work for 2013

- Update 2012 HIRAD thermal model to simulate 2012 flight data
  - Add brackets and controllers to model
  - Remove fiberglass insulation
- Correlate model to latest collected data
  - Adjust effective heat loss if needed
  - Compare model with heater set points of 25 ºC to 2012 flight data
- Recommend changes to the heater locations and set points to maintain a constant temperature of <u>each</u> receiver throughout flight.
- Determine placement of instrumentation for environmental chamber testing to assist future model correlation

2013 Thermal Modeling

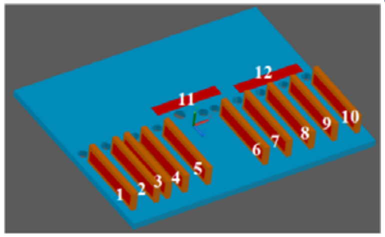
- Changes made to 2012 model:
- Components removed
  - Fiberglass insulation
- Components added
  - Antenna split into two pieces
  - Bracket frame and clips
  - Controllers
- Location of heater set point corrected
  - Measured from outer aft surface of receivers

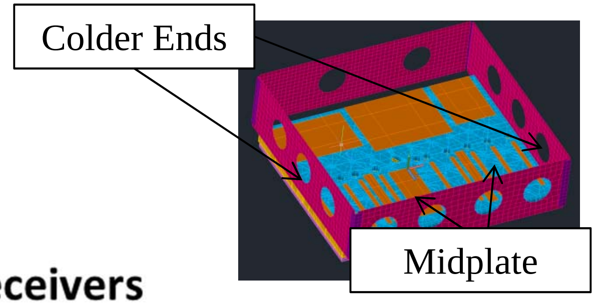


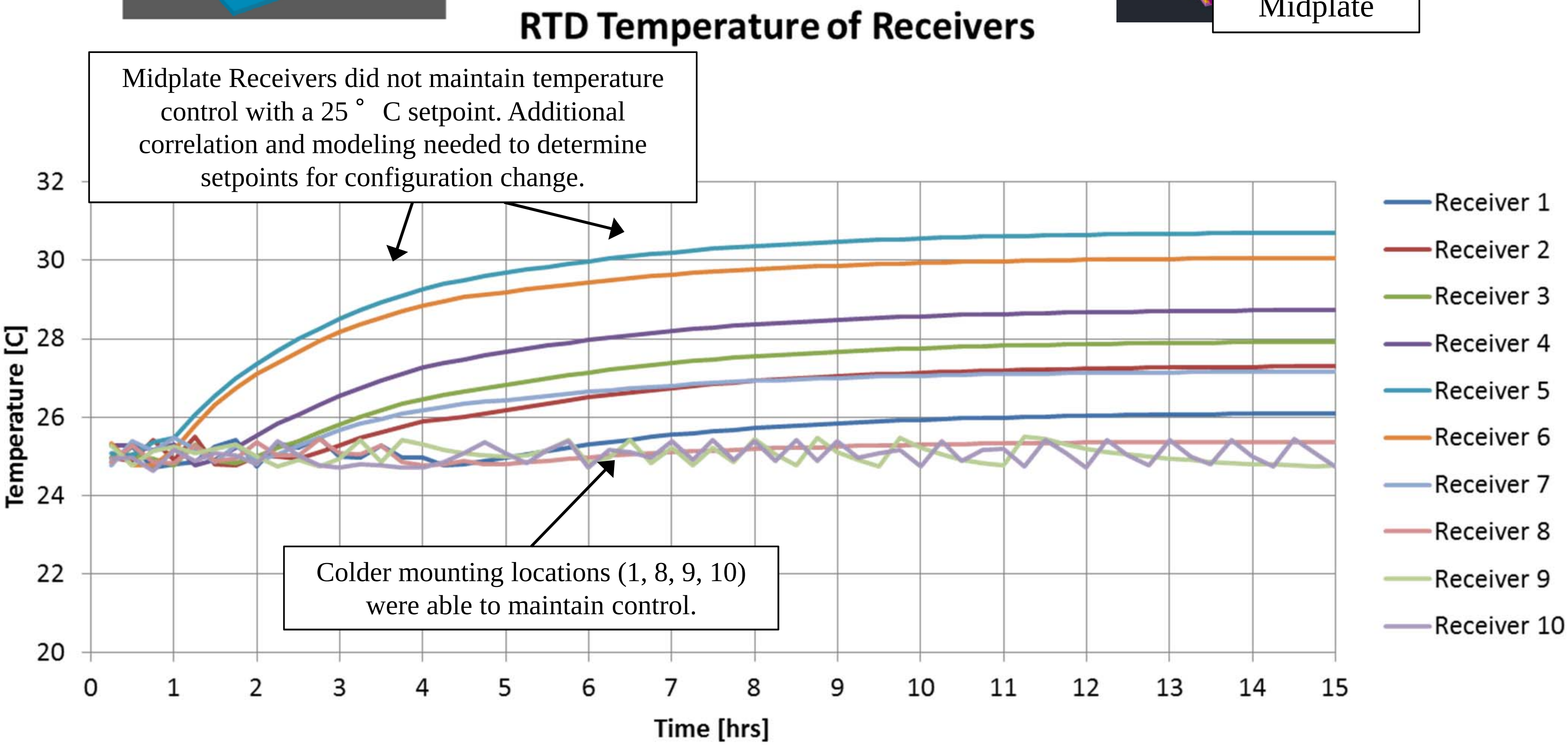


Receiver Temps of 2013 Correlated Model

- Constant boundary temperature: -60ºC



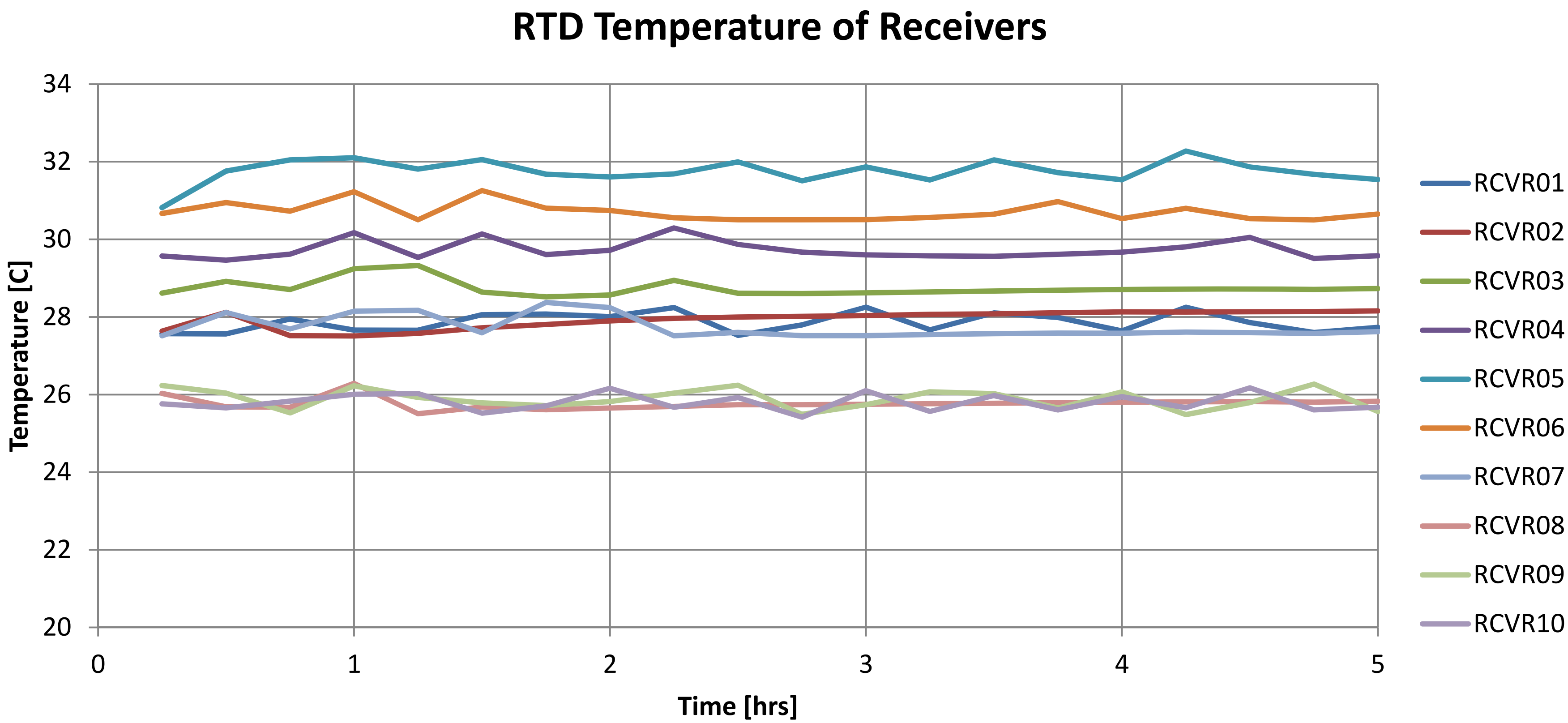




Recommendation Based on 2013 Model

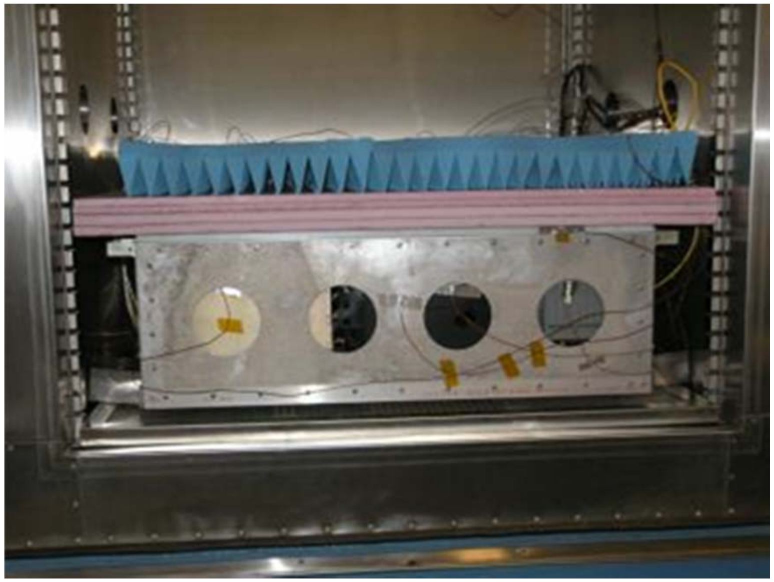
- Set temperatures based on model temperatures reached without heaters

RCVR	1	2	3	4	5	6	7	8	9	10
Set Temp ± 0.25 °C	27.75	27.75	28.75	29.75	31.75	30.75	27.75	25.75	25.75	25.75



2013 Environmental Chamber Testing

- Thermocouple locations requested
  - Around edges of mountplate
  - Mountplate near receivers
  - Temperature inside MLI blanket
  - Temperature of bracket
- Test Set up
  - Assembly positioned upside down
  - MLI blanket NOT included
  - Different brackets used
  - Fiberglass insulation over antenna



- Preliminary Observations
  - No MLI blanket = receivers are more easily controlled by heaters due to increased cold environment
  - Receiver temperatures are impacted by adjacent receiver heating levels
  - Fiberglass insulation causes a longer amount of time needed to reach equilibrium temperatures

2013 Flight Recommendations

- Not to include the MLI blanket
  - Receivers can be controlled at a lower temperature
- Set temperatures in real time
  - Set temperatures of outer receivers first (in cooler locations)
  - Determine temperatures of inner receivers once outer receivers have reached steady temperature.
- Requested additional temperature sensors
  - Air temp of HIRAD environment
  - Air temp inside MLI blanket (if blanket is used)
  - Temperature of Radome
  - Mountplate temperatures

Planned Configuration for 2013

- August 20 – September 23
- MLI blanket folded over frame, covering top of receivers, controllers, and LO
  - Remaining in assembly to protect from possible fuel or oil leaking
  - Not covering sides of components up to height of frame
- No fiberglass insulation will be used
- Set points to be adjusted during flight

Conclusion

- Completed modeling and analysis
  - 2012
    - Created and correlated model based on flight data with no heaters
    - Modeled 2 heater layouts at several set temperatures to determine most effective heater placement
    - Recommended heaters on receivers with set points 28-31ºC
  - 2013
    - Updated and correlated model based on flight data flown with heaters on receivers at set point of 25ºC
    - Recommended to remove MLI blanket and set heater temperatures in real time
- Forward Work
  - Analyze environmental chamber test results
  - Correlate model to test results
  - Analyze 2013 season data
    - Recommend changes based on flight data and further analysis

Lessons Learned

- Clearly define goals of modeling and reasoning behind goals
- Organize models through labeling and descriptive titles
- It is very helpful to see hardware in person to visualize problems
- Thoroughly document results
- Ask lots of questions!