Space Dynamics LABORATORY
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# Microgravity Testing of Phase Change References on the International Space Station

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# Need for Orbital Temperature Reference

- Phase transition cells for absolute temperature reference are key components of any future climate monitoring mission.
- Mission requires:

  "…an SI-traceable standard for absolute spectrally resolved radiance in the infrared with high accuracy (0.1K 3σ brightness temperature… Each of the interferometers carry, on-orbit, phase transition cells for absolute temperature,… with SI traceability [1]."

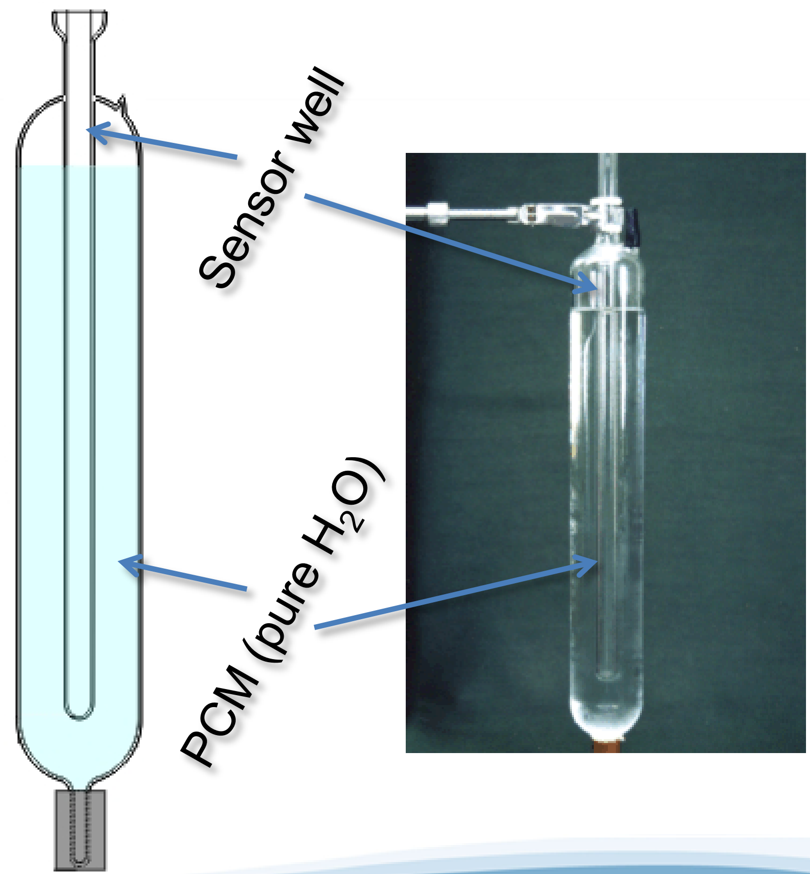
- Because the temperature uncertainty will only be one of the contributors to the 0.1K requirement absolute temperature uncertainty will need to be lower, on the order of 0.01 K or better.

# Phase Transitions as References

Traditional Triple Point of Water Cell.

- Large volume of PCM
- Long melt times
- Deep reentrant
- No in situ sensor calibration
- Fragile container
- Detailed manual heating and cooling procedures

Practical absolute uncertainty, 0.1 mK or better [2,3]



# Flight Realizations of Fixed-Point Cells

- Miniaturization of hardware necessary for limited mass, volume, time, and power resources
  - Smaller sensors
  - Optimized PCM volume
  - Minimal Thermal Controls
- Automation of phase transitions & data collection
- Interpretation of data and absolute accuracy of fixed-points
- Sealed, rugged, non-contaminating PCM containment
- Minimization of time to carry out a phase transition
- Minimization of gradients and offsets in measurements
- Transfer of calibration to in situ temperature measurements

# Planned Flight Testing

- Previous studies have shown that crystallization in Gallium alloys is altered by zero gravity conditions [4,5].
- PCM references need to be tested in space to characterize any possible anomalies in their behavior and to evaluate the effectiveness of design tradeoffs.
- SDL has several experiments planned for the ISS;

**1st & 2nd** Flight experiments will test a single Gallium cell design and a triple cell design with Ga, GaSn, and water.
**3rd** Flight experiment will test variations to the 3 PCM design with smaller PCM volumes.

# ISS Experiment Package

Internal Electronics | Experiment Module | Power Module

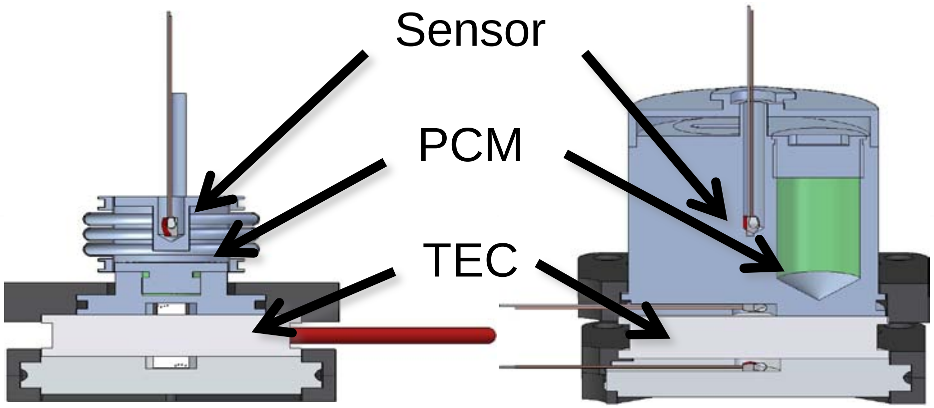
12" Ruler

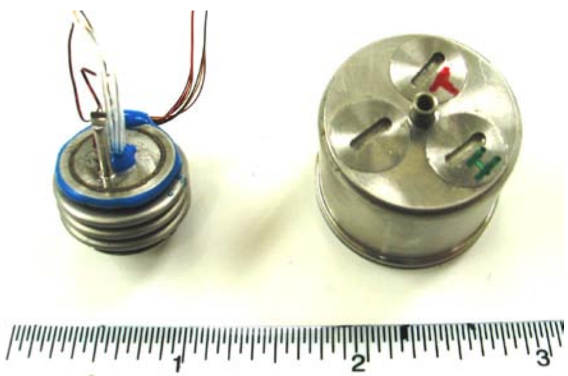
- Experiment module capable of thermal control and measurements of different cell designs.
- Experiment is automated by a Tern embedded computer and electronics.
- Experiment module is returnable on Soyuz.

# Flight Cell Designs (1st & 2nd Experiments)

## 1st experiment:

- Single PCM Gallium
- sealed SS container
- Container allows for PCM expansion.
- Reentrant well for sensor in PCM
- PCM volume ~1mL
- TEC allows heating and cooling of PCM.




## 2nd experiment:

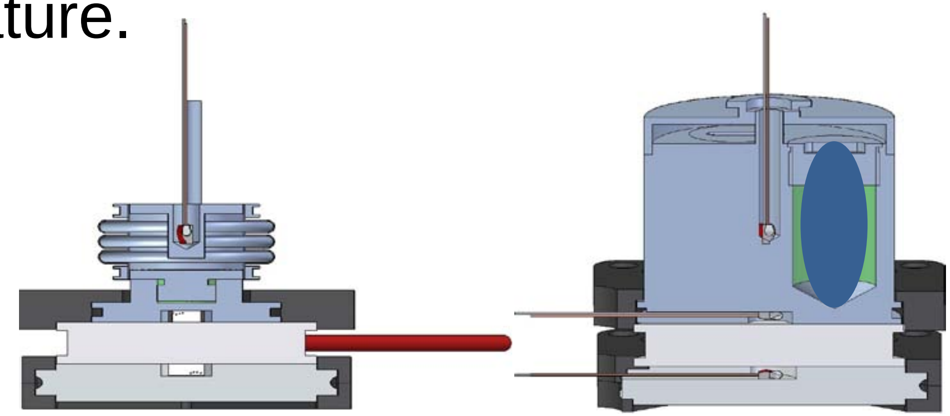
- 3 PCM Gallium, Gallium-Tin eutectic, and water
- sealed SS container
- Compressible trapped gas allows for PCM expansion.
- Sensor in container adjacent to PCM
- PCM volume ~0.75mL (each)
- TEC heats and cools PCM.

# Sealed Cells vs. Pressure Dependence of Fixed-Point

- For contamination issues PCM containers must be sealed.
- 1 atm pressure changes melt temperature of water by 10 mK [3].
- Container must allow PCM expansion without changing fixed-point temperature.

Flexible container:

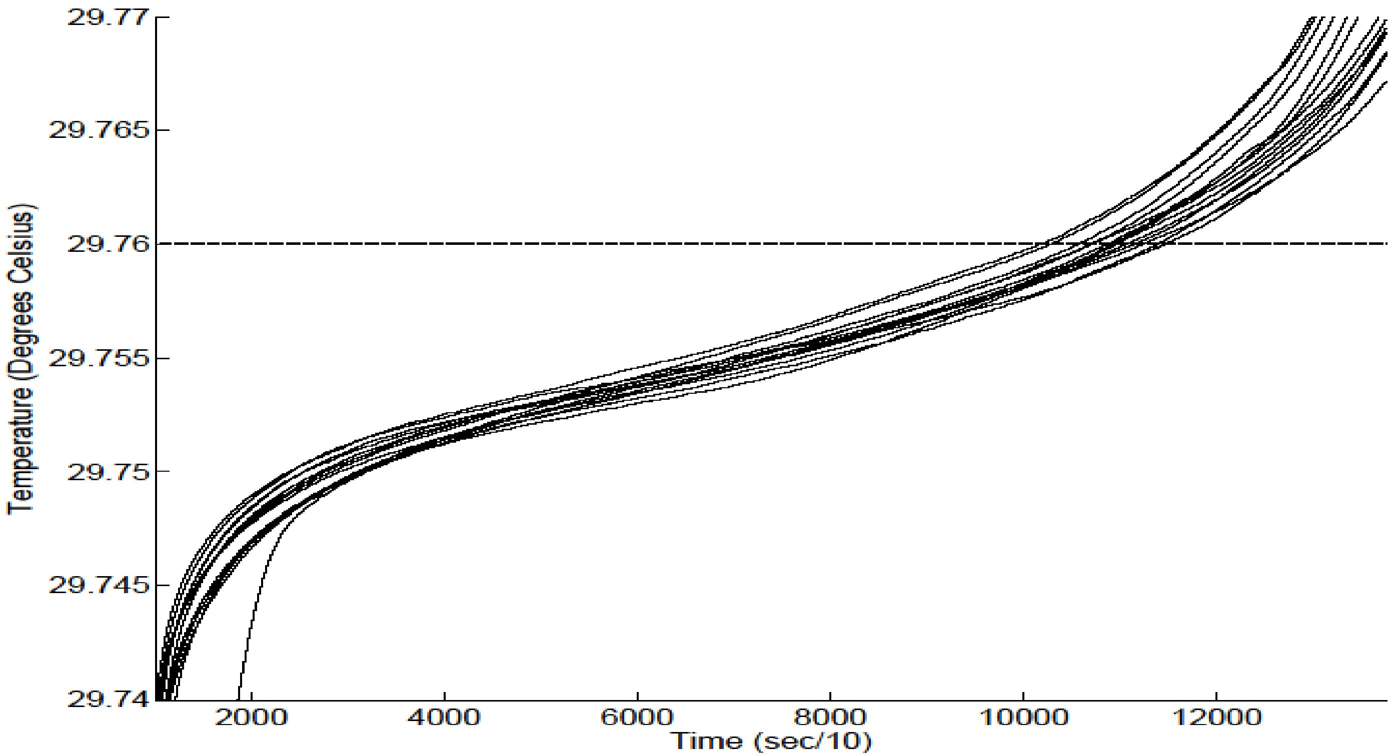
-No internal voids
-PCM can expand container
-PCM vacuum filled
-complex filling
-complex container
-moving parts



Rigid container:

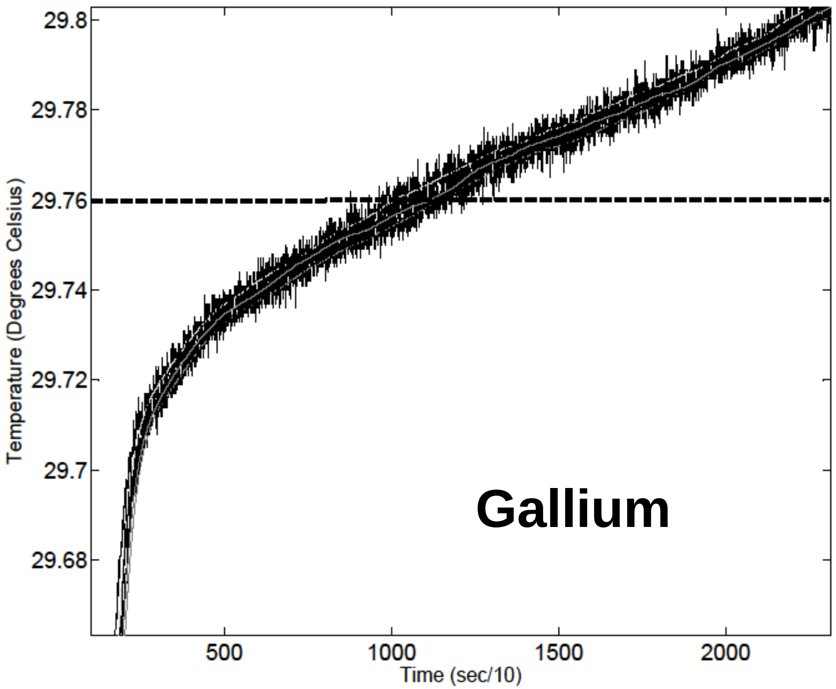
-PCM filled at 1 atm
-Internal gas voids compress as PCM expands.
-location of voids in space?

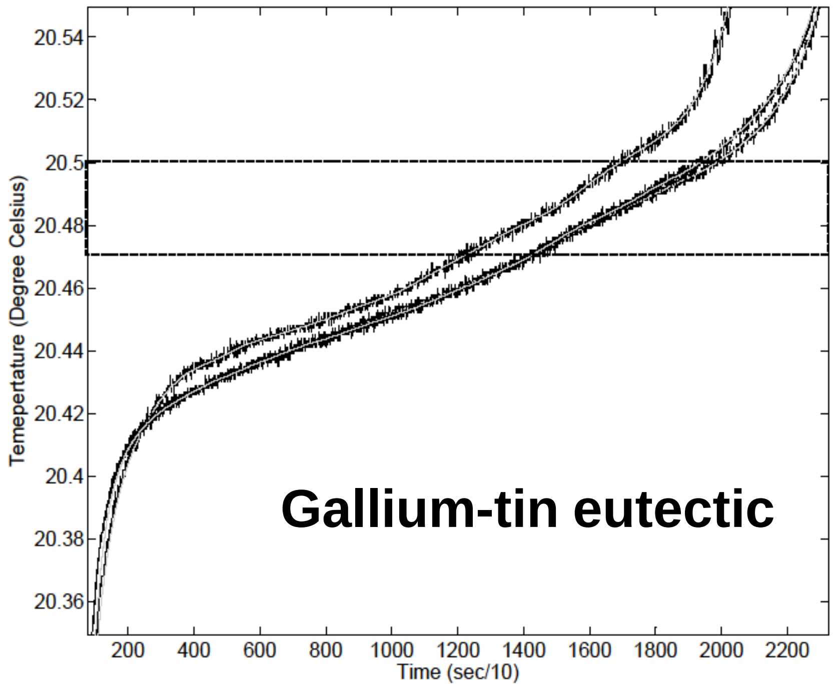
# Flight 1, Pre-Flight Experiment Simulation




Gallium melt data collected from first flight unit mock flight experiment over 1 week in open lab environment with ambient temperature fluctuations similar to ISS (±3 C)

# Flight 2, Pre-Flight Experiment Simulation




Melt data collected from second flight unit during characterization and software algorithm development

# Current Status of Experiments

- Flight 1 experiment hardware was delivered to Moscow Dec. 2010.
- Flight 2 experiment package was delivered Feb. 2011.
- Approvals for manifest on Progress under negotiation with tentative agreement for experiments to be conducted on ISS by the end of 2011.

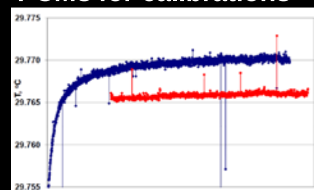
*F1 in Moscow*

*F2 in Moscow*

# Historical Timeline

VEGA Intl. approached to collaborate on gallium eutectic work

Vega Results show Eutectics as viable PCMs for calibrations




ESTO office begins funding support to speed development to benefit CLARREO with space qualification results

Launch opportunities delayed by Russian Calibration Institute approvals with ties to VEGA

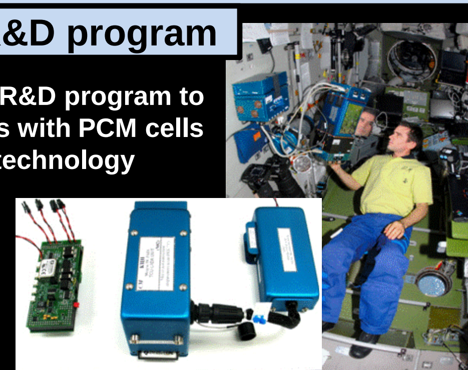
| 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|
| | | | FY1 | FY2 | FY3 | FY4 | |

SDL IR&D program

(2004) Initial internal studies of potential for NPOESS started

(2006) IBMP approached to provide ISS testing of PCM cells.

SDL starts IR&D program to get ISS tests with PCM cells and patent technology



Planned ISS experiments

# Diagram of Contributions

Energia provides: Hardware launch and station resources.

NASA provides: research funding, hardware/plant tissue return, hardware design input.

-Data is shared by all participants.
-Hardware and tissue samples are returned by Shuttles and Soyuz.

Intl. Cooperative Agreement

SDL provides: Internal research funding, hardware construction, data analysis, program management

IBMP provides: Hardware qualification, station flight support for experiments, data analysis, internal research funding

# Summary

- ISS experiments will evaluate tradeoffs and resulting data will increase confidence in utility of microgravity PCM references.
- Flight units delivered to Moscow awaiting launch later this year.
- Negotiations for launch manifest have been uncharacteristically slow but appear to be over the major hurdles and progressing.

# References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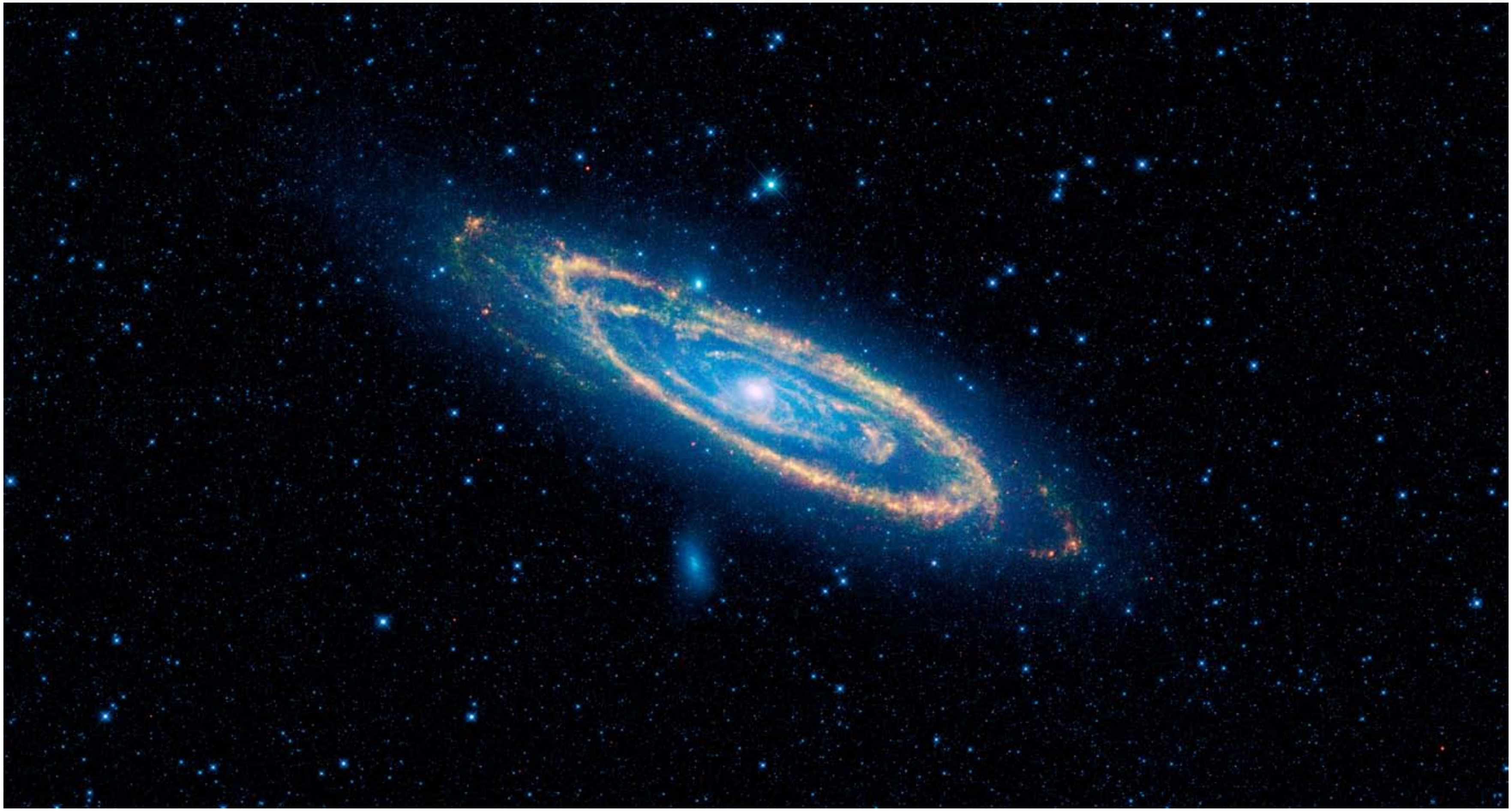
# Questions?



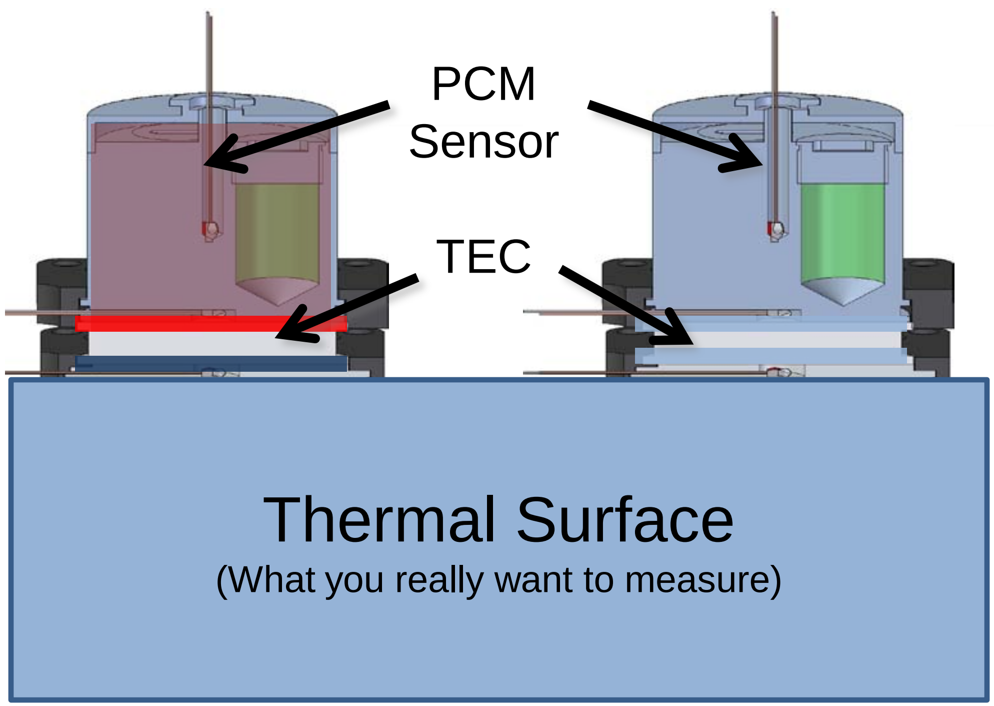
# Additional Slides

# Transfer of Calibration

## Calibration:

During a recalibration the TEC is powered and the PCM is controlled to a different temperature than the thermal surface to melt the PCM.

Temperature data collected during the melt allows recalibration of the PCM sensor.




## Transfer:

When the TEC is not powered it acts as a thermal link to the thermal surface.

If adequately insulated it will come to equilibrium with the thermal surface.

The PCM sensor can be compared to thermal surface sensors' readings.

# SDL Temperature Sensor Testing

- Heraeus PRT and GE thermistor excellent size and long term stability [6,7].
- GE Thermistors tracked standards PRT ±3mK, with calibration improvement to ~1mK.
- Heraeus PRTs tracked ±10-15mK (worse than larger wire PRTs).
- Heraeus shock resistance 40g at 10-2kHz