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Technology to the next degree™

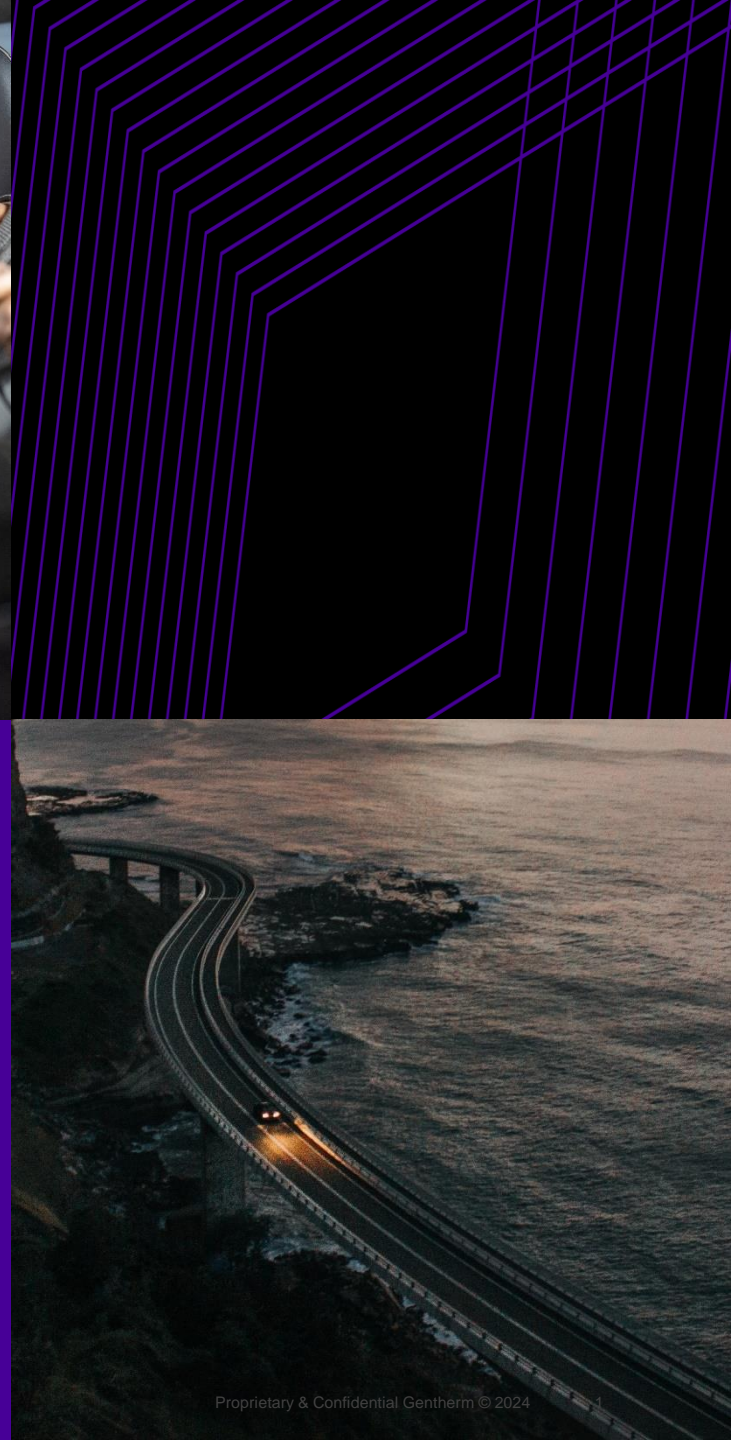


Powering Smart and Efficient Heating Through Virtual Sensing

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Thermal Management Expo

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Standard



Manual control, static settings

- Pre-set levels (Hi/Med/Lo)
- Safety timers limit total heat time
- Correlation tuning varies by condition
- Auto stepdown logic rigid in practice



Smart Surface Control



Identify surface needs in real time

- Software-based virtual sensing
- Closed loop surface temperature control
- Consistent heating across all scenarios
- Improved remote start heating



Coordinate multiple surfaces

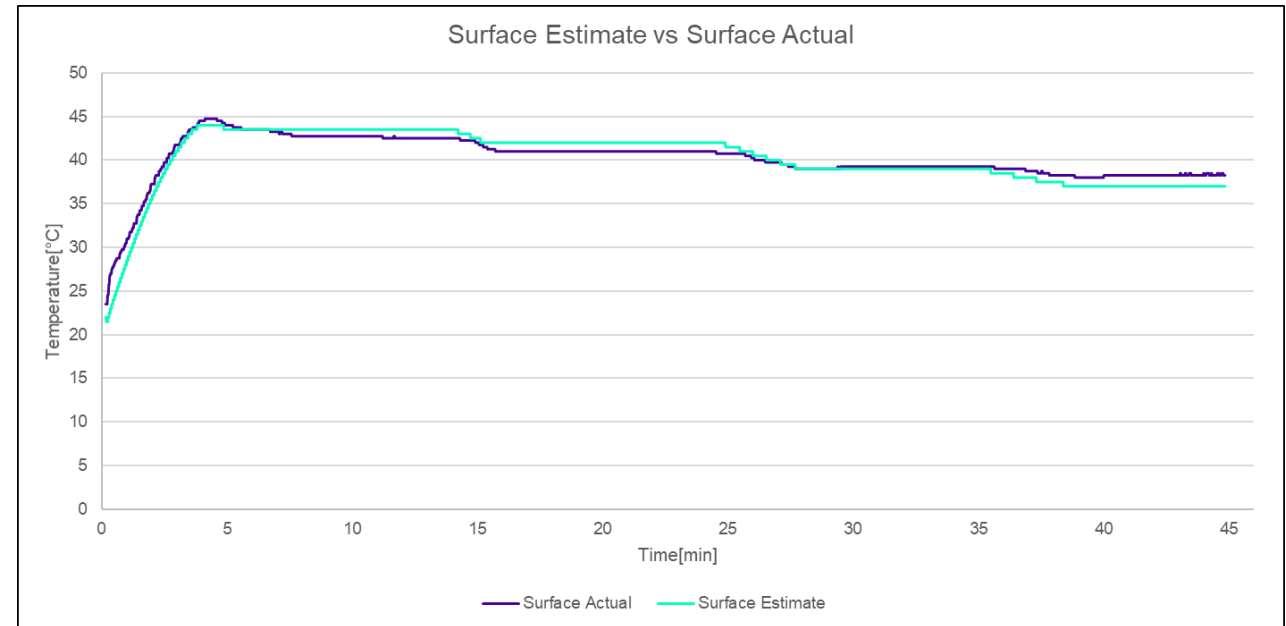
- Auto-adjusts to cabin temperature
- Syncs with HVAC for optimized comfort

Maximize the heating potential of the hardware with smarter logic

Inside the Virtual Sensor: How to Estimate Without Measuring

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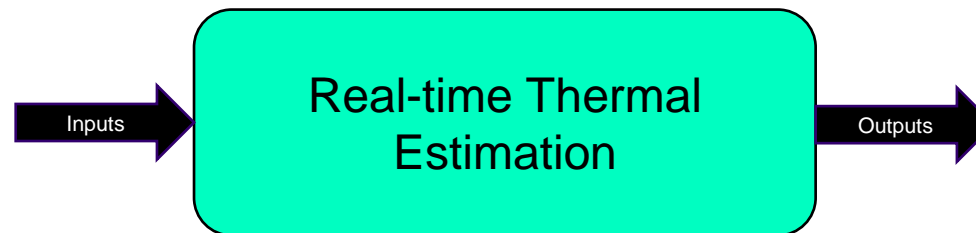
Physics-based
surface temp
estimation



Physics-based model estimates within $\pm 1.5^{\circ}\text{C}$ of measured surface across dynamic conditions

What is used to model surface temperature:

- Heater temperature, Current, Voltage
- Cabin air temperature
- Seat material properties
- Thermal resistance / capacitance
- Occupancy status
- Clothing assumptions



What can be calculated:

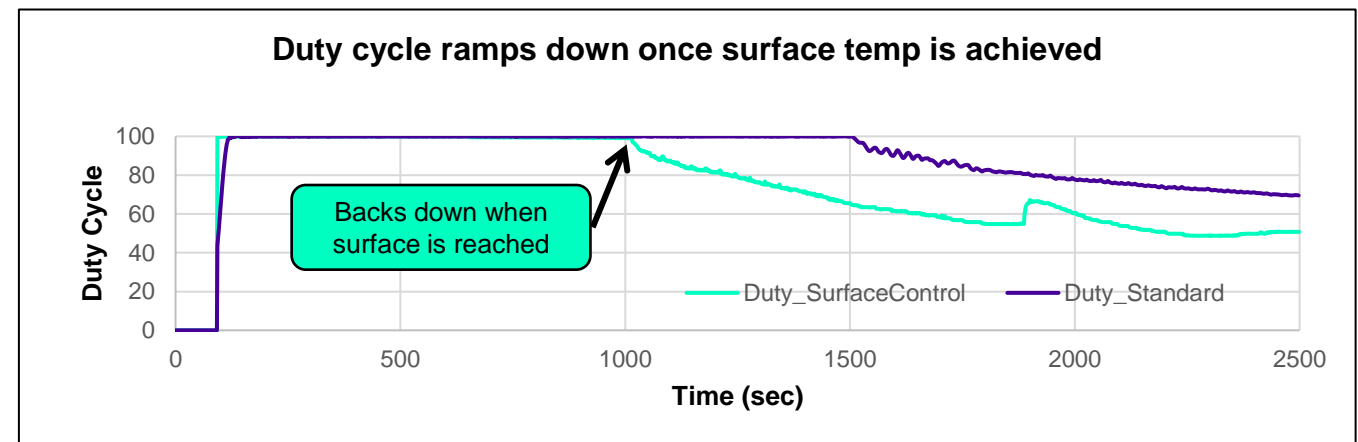
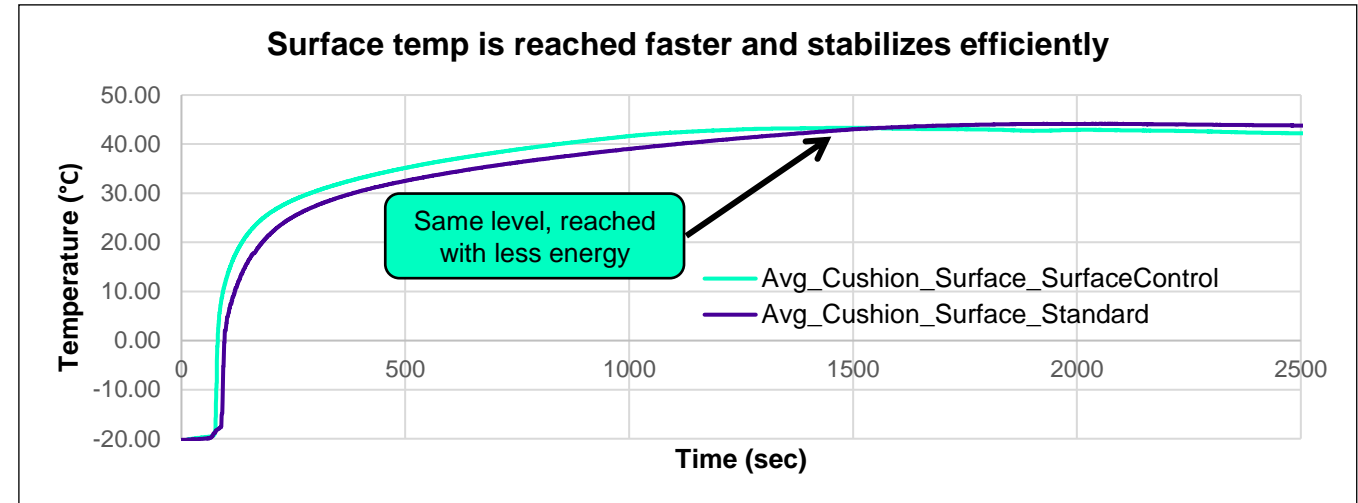
- Estimated surface temperature
- Power needed to maintain target
- Thermal system health (DTCs, Diag)

Precisely control surface temperature to maximize occupant comfort in real time

Use Case: Reducing Energy Through Smarter Surface Heating

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- Traditional systems heavily rely on timers and are not aware of the actual temperature the occupant is experiencing
- Virtual sensing enables temperature-driven, closed loop control optimizing energy based on actual need
- Test conditions
 - -20°C Ambient
 - Human Occupant
 - High Heat Set Point
 - North American OEM Seat
 - Standard Control vs Smart Surface Control
- Smarter logic reduces duty cycle earlier, maintaining comfort while saving energy

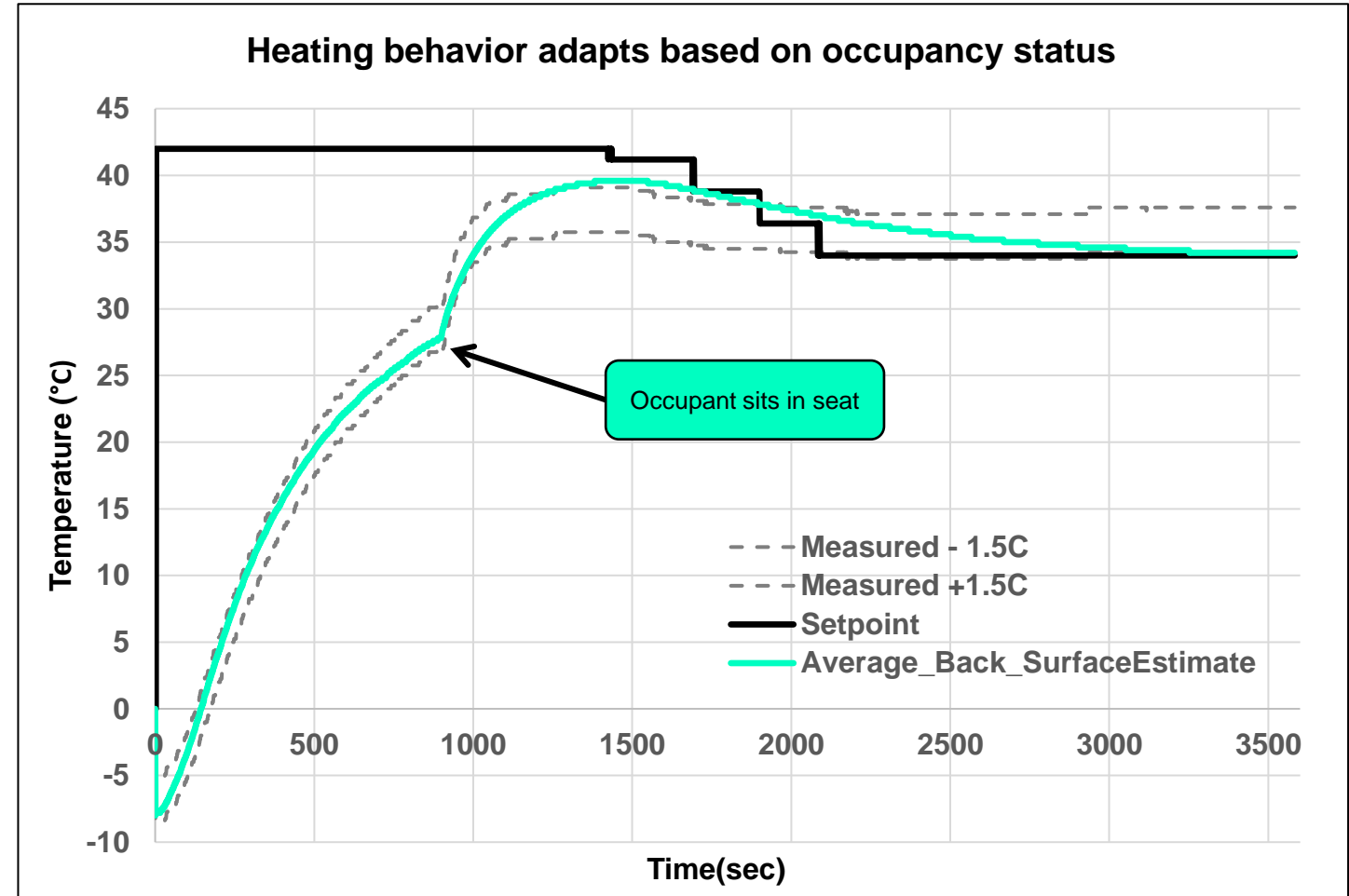


Energy savings are unlocked by understanding the surface and controlling accordingly

Use Case: Virtual Sensing Improves Remote Start Comfort

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- Tracks surface temperature during unoccupied and occupied phases
- Precisely regulates heat to reach the target temperature, avoiding underheating or overshooting to ensure the seat is ready at entry



Surface estimate accounts for occupancy status to optimize heat delivery and maintain target temp

Enabling intelligent pre-conditioning – adapting in real time to occupancy and surface conditions

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