Reduction in Vehicle Temperatures and Fuel Use from Cabin Ventilation, Solar-Reflective Paint, and a New Solar-Reflective Glazing

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Outline

- Improved Mobile Air Conditioning Cooperative Research Program
- Vehicle Thermal Soak Test
- Thermal and Vehicle Fuel Use Analysis

Improved Mobile Air Conditioning Cooperative Research Program

- Demonstrate technologies to reduce direct (leakage) and indirect (tailpipe) HFC-134a refrigerant emissions
- Government/Industry partnership
- 28 Industry Sponsors
- Administered by Society of Automotive Engineers (SAE)
- Four Teams
  - Reduce leakage during operation
  - Improved COP
  - Reduce vehicle thermal load
  - Reduce leakage during service

2006 I-MAC Reduced Thermal Load Vehicle

Select the most promising technologies and test in a final configuration

Solar Powered Parked Car Ventilation

Solar Reflective Glazings

Solar Reflective[4] Paint

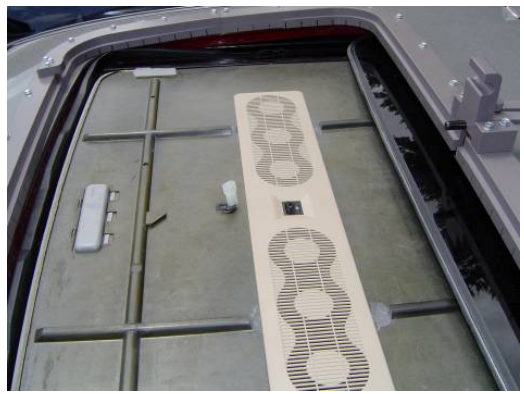
Solar Reflective Glazings: Sungate EP

- Manufacturer: PPG Industries
- Reflects IR portion of solar spectrum
  - Meets 70 % transmittance requirement
  - Greater than 50% solar energy reflected
- Reduces solar heat gain
- Windshield, sidelites, backlite

	Solargreen® glass	Sungate® windshield	Sungate® EP
LTa	72%	72	71
TSET	44%	39	33
TSER	6%	31	47

Solar Powered Parked Car Ventilation

- Manufacturer: Webasto
- 24 cell, 17 W PV panel in sunroof
- Six ~ 1.6 W fans
- Current configuration: Extracts hot air from cabin interior
- Since STS already had a sunroof, a unique test install was required



Solar Reflective Paint

- Manufacturer: PPG Industries
- Prototype S2X
- Maintains color while reflecting IR portion of solar spectrum
- Standard clearcoat over IR reflective basecoat
- Cooler skin temperatures reduce cabin heat gain
- NREL measured absorptance
  - Baseline 89.4%
  - Solar reflective 82.1%

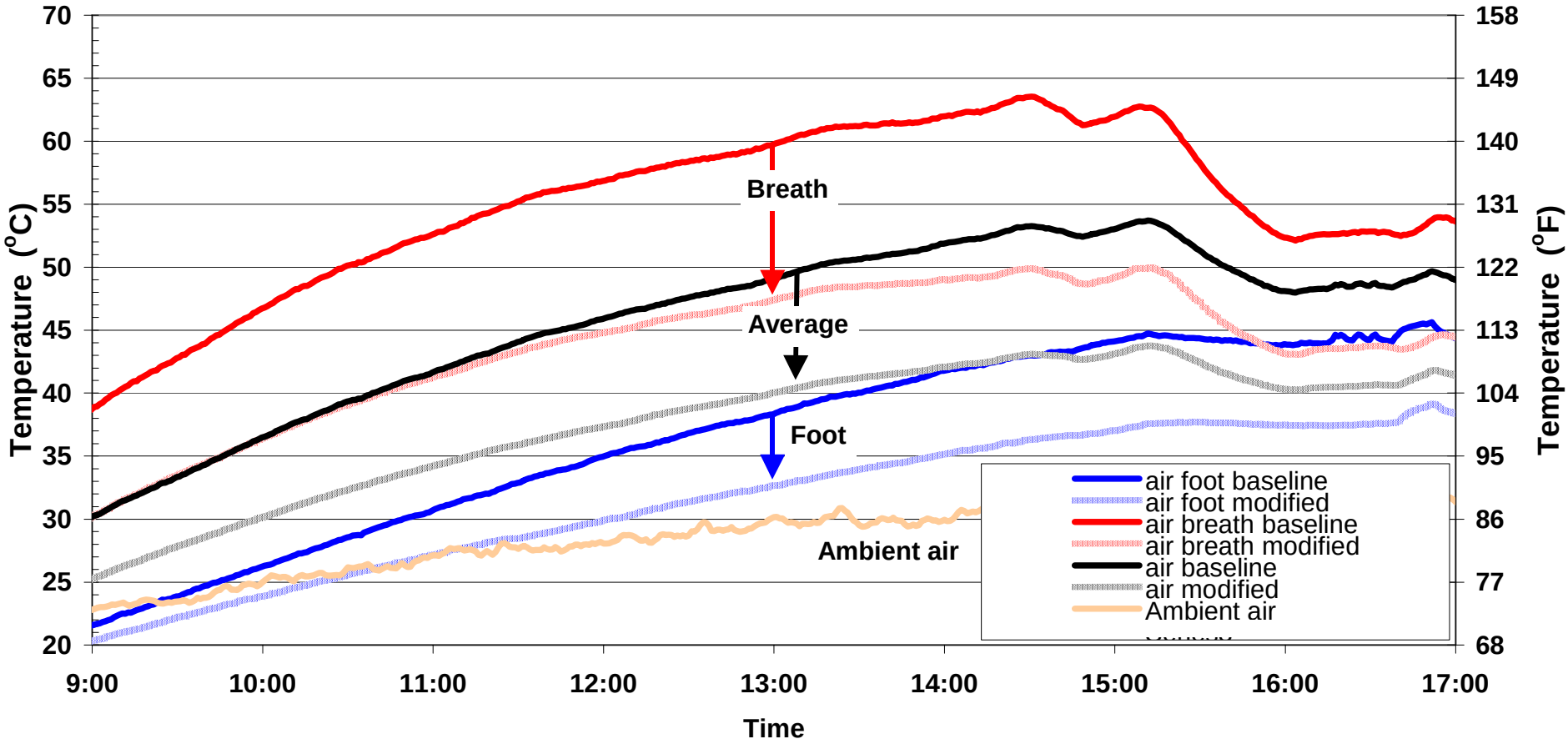
I-MAC Vehicle Soak Test Procedure

- Two nearly identical vehicles parked facing 160º, front/back
- Evaluate technologies that reduce thermal load
  - Modify test vehicle
  - Start data acquisition system ~ 8:30 am
  - Stop data acquisition system ~ 16:30 am
- Data analysis
  - Report time-averaged temperature difference between identical locations between 12:30 and 13:30
  - Eliminate cloudy days
  - Average results with multiple “good” test days

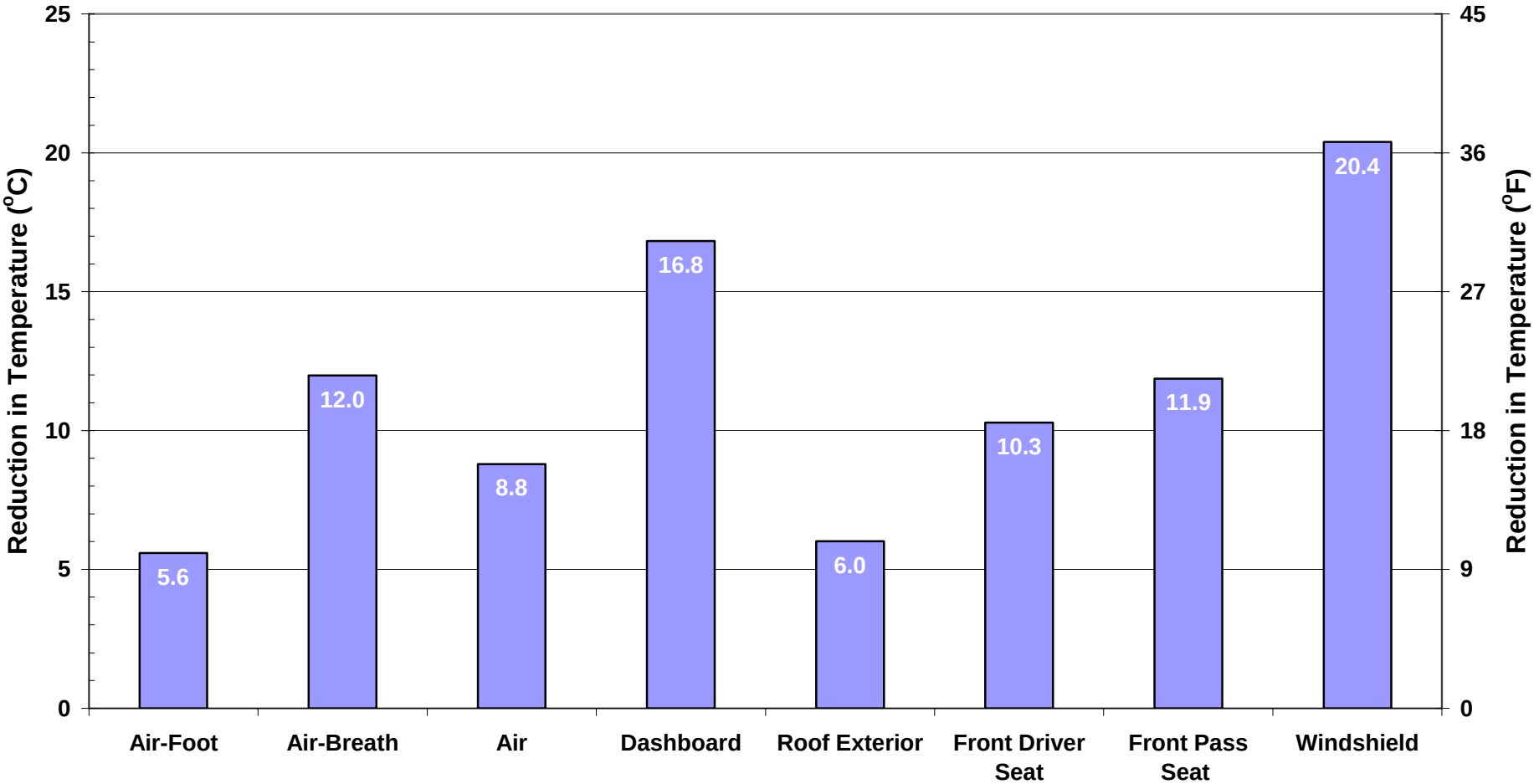
Cadillac STS & NREL Test Facility

Reduction in Air Temperatures

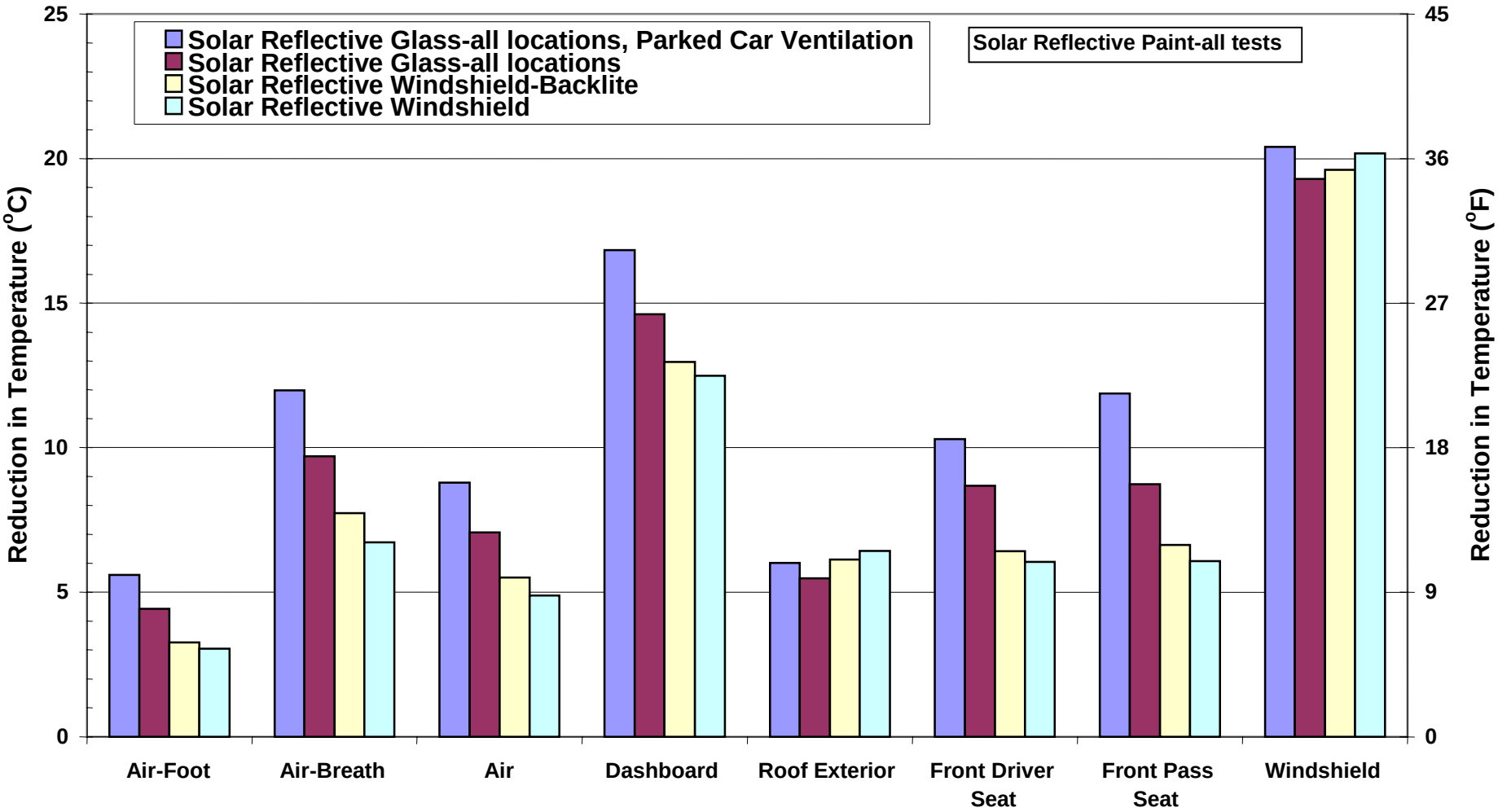
Solar reflective glazings all locations
Solar powered ventilation
Solar reflective paint



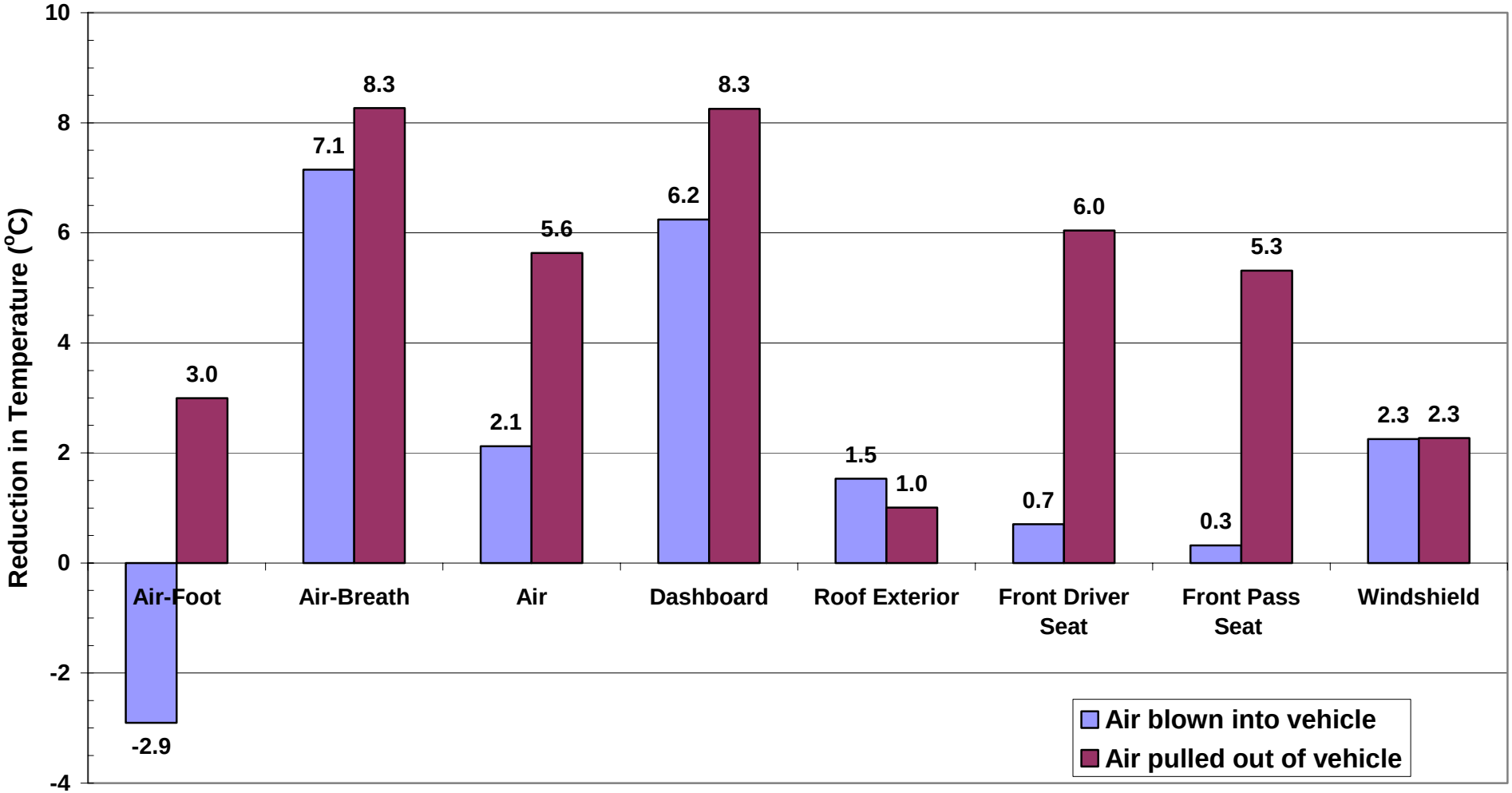
Solar Reflective Glass (All Locations), Paint, and Ventilation



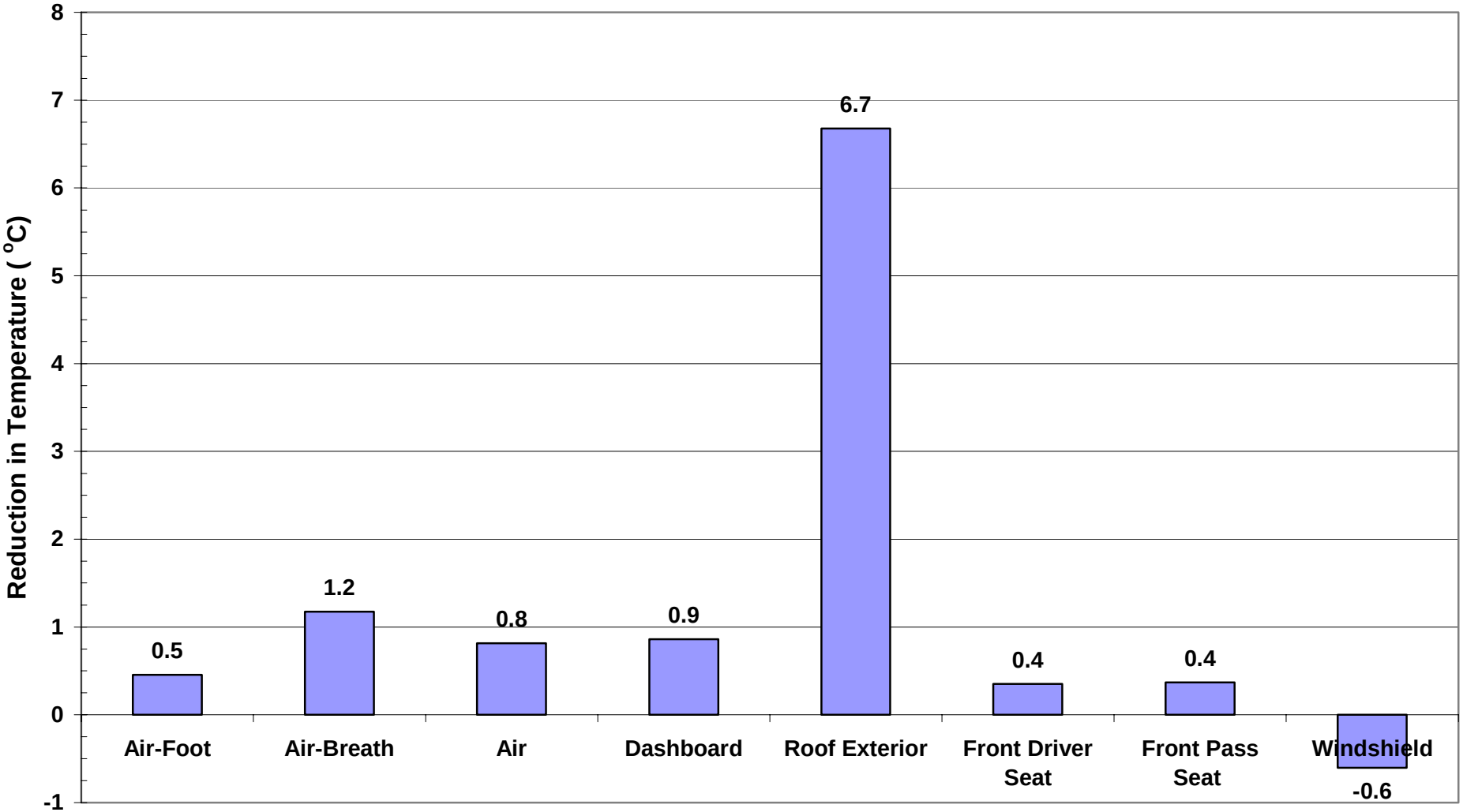
Comparison to Solar Reflective Glass only Data



Solar Powered Ventilation Only

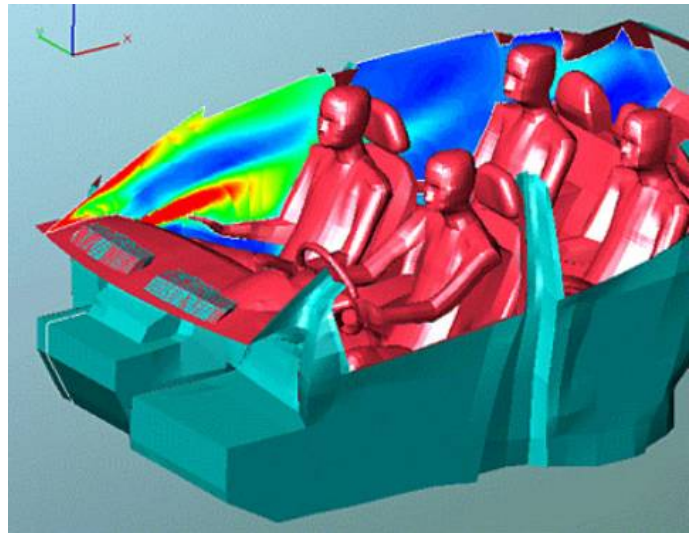


Solar Reflective Roof Film Only



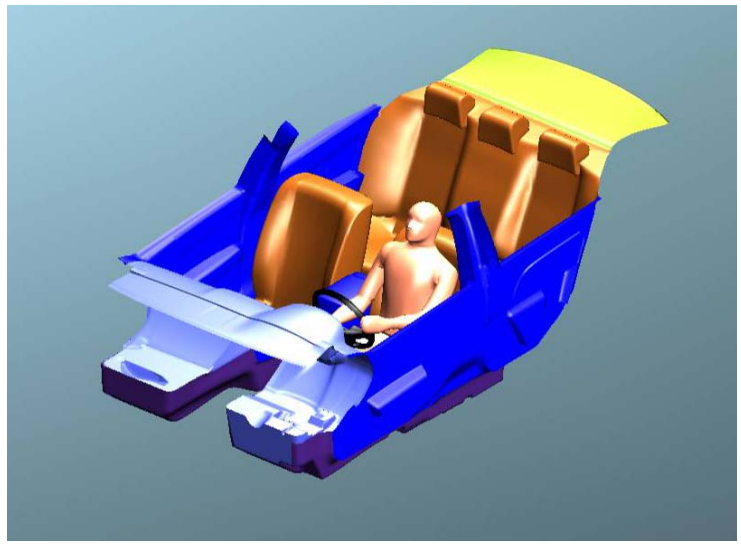
Integrated Modeling

Assessing the impact of advanced climate control systems on vehicle fuel use and human thermal comfort in a Cadillac STS



Integrated Modeling

Model temperatures and airflow in the cabin



CAD

Cabin Thermal/Fluid

RadTherm

Air Conditioning

Vehicle

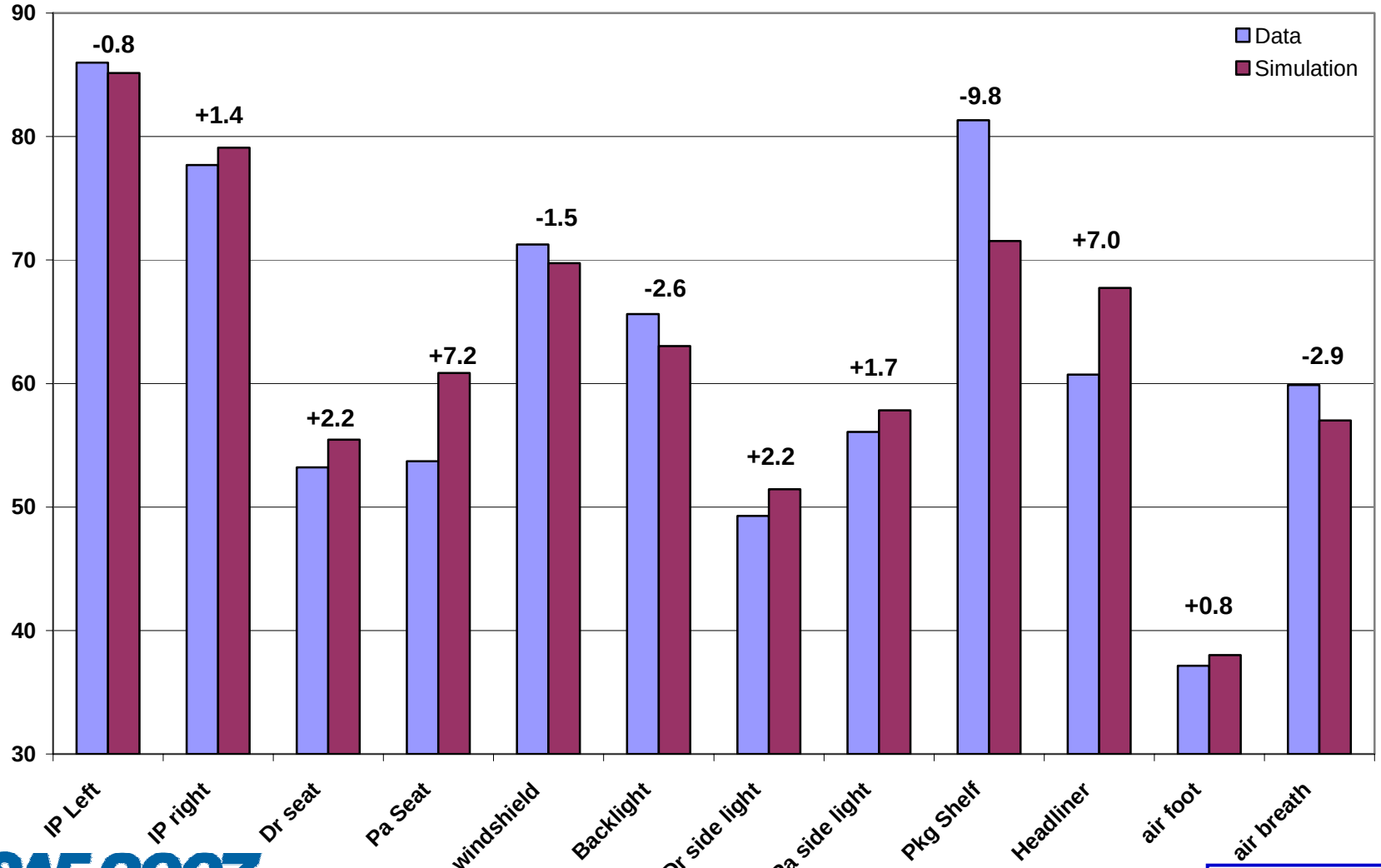
Thermal Comfort

Fuel Economy

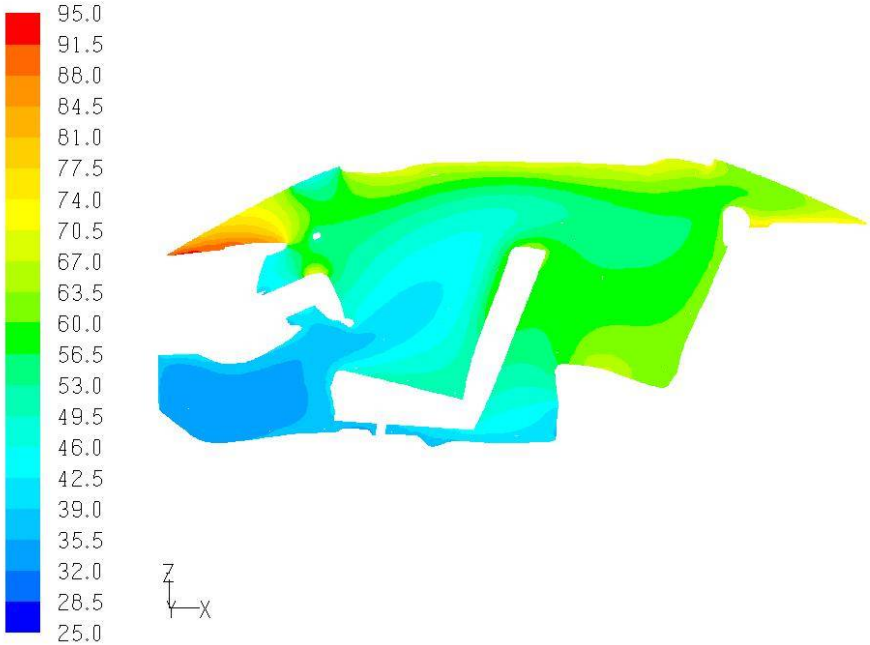
Tailpipe Emissions

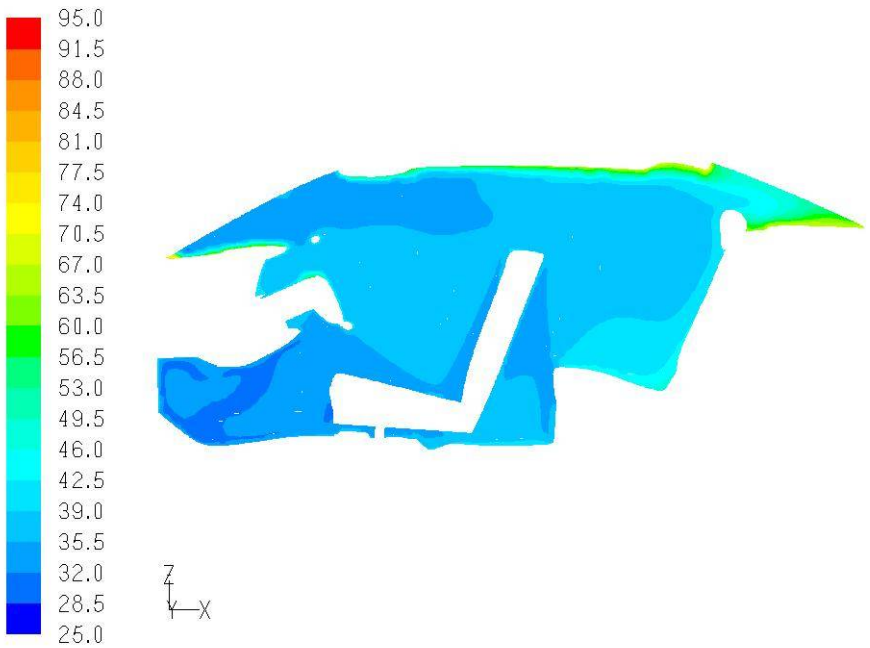
Occupant Thermal Comfort

Baseline Soak Results Comparison to Test Data



Soak Results Temperature Contours





Baseline

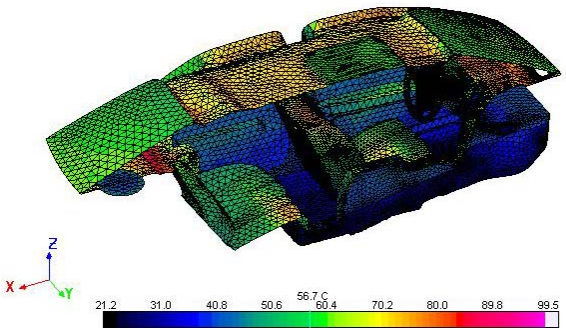
Reduced Thermal Load

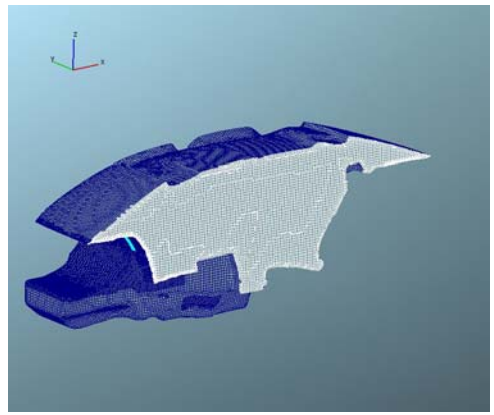
Solar Reflective Glazings
Solar Reflective Paint
Solar Powered Parked Car Ventilation

Simplified Thermal Model

RadTherm

Fluent

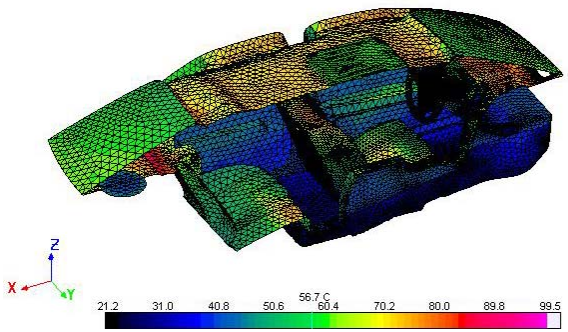


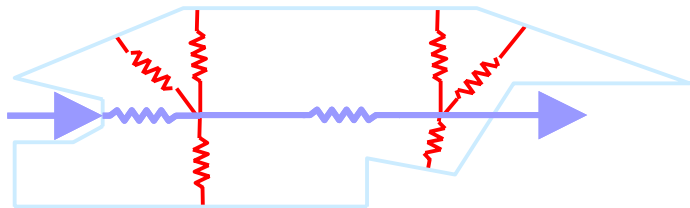


136,000 Elements

Full CFD model

900,000 Fluid Nodes



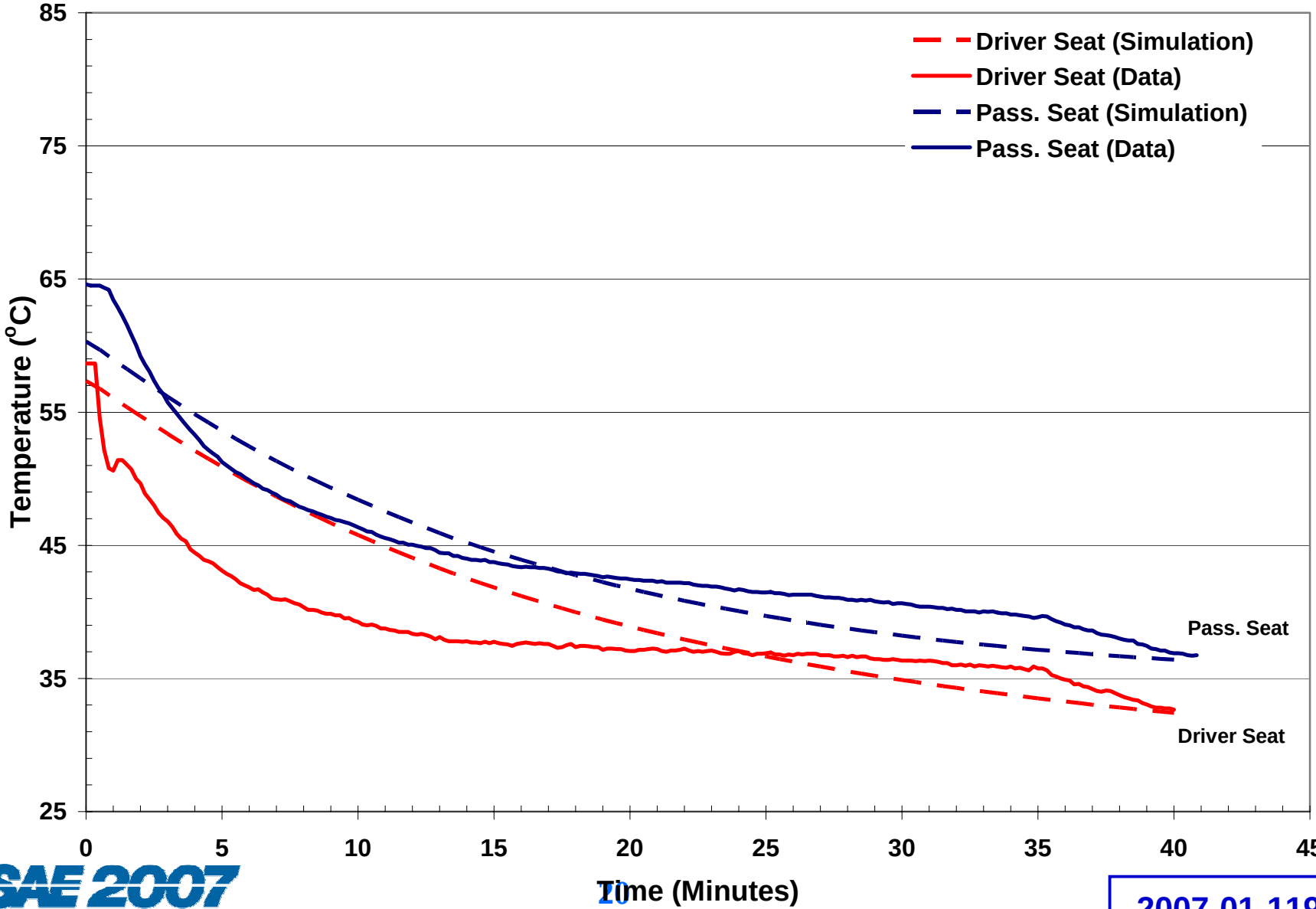


136,000 Elements

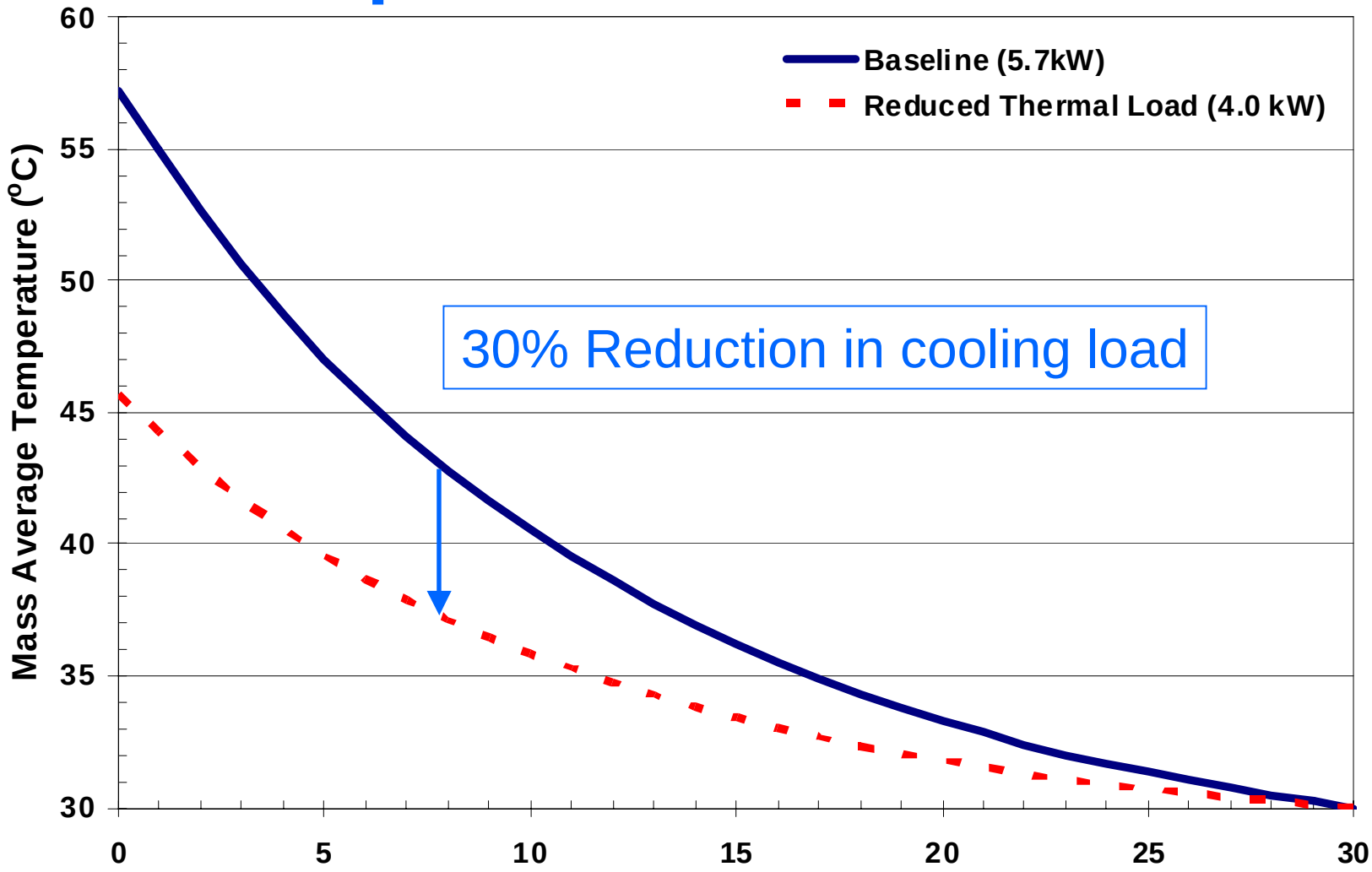
Simplified model

8 Fluid Nodes

Baseline Cool Down Results



Adjust A/C Load in RadTherm to Achieve Equal 30 min. Cooldown



30 minute cool down

- Heat Balance:

$$\sum_{t=0}^{t=30}\left(\dot{m}C_p\Delta T\right)_{Air,Baseline} - \sum_{t=0}^{t=30}\Delta Q_{Solar} - \sum_{Soak}\Delta Q_{Solar} = \sum_{t=0}^{t=30}\left(\dot{m}C_p\Delta T\right)_{Air,ReducedThermalLoad}$$

$$\Delta T = T_{AirExit} - T_{AirInlet}$$

$$\Delta Q_{Solar} = Q_{Solar,Net_{Baseline}} - Q_{Solar,Net_{ReducedLoad}}$$

- Balanced with:

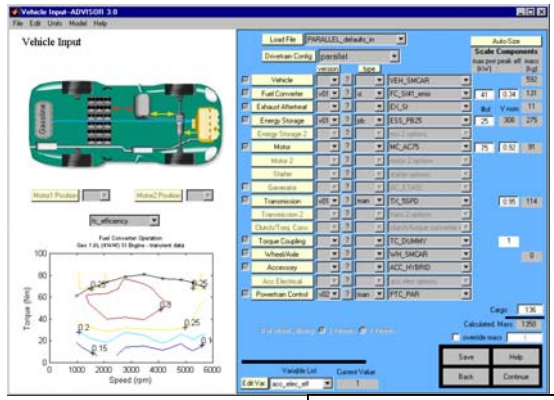
  Baseline – 5.7 kW cooling

  Reduced Thermal Load – 4.0 kW cooling

- 29.8% Reduction in cooling load

Integrated Modeling

Model the STS over a drive cycle and find the fuel use



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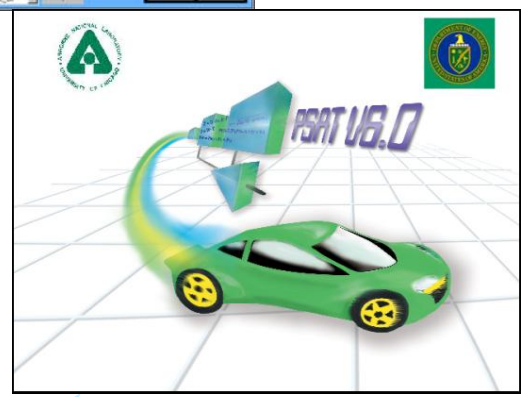

CAD

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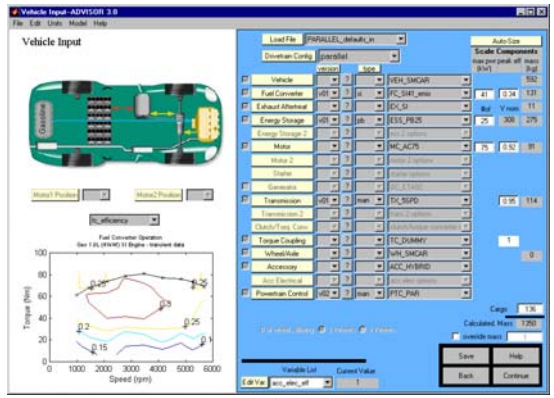
Impact on Fuel Economy

- Vehicle simulator used to assess impact of reduced AC load.

City	Highway
16	24



Fuel Economy (mpg)	FTP Drive Cycle
Fuel Economy no AC	18.5
Fuel Economy with Baseline AC	15.4
Fuel Economy with 70% Baseline AC	16.1

Impact on Fuel Use

- US Average AC use - 32.6% (MAC Summit 2004)
- US Vehicle Miles Traveled - 11,998 (Wards 2005)

Annual Fuel Used per Vehicle for AC (gal)	FTP Drive Cycle
Fuel Used with Baseline AC	42.6
Fuel Used with 70% Baseline AC	31.4
Fuel Savings per Vehicle	11.2

26 % Reduction in AC fuel use for this vehicle

Conclusions

- Significant reduction in cabin interior temperatures demonstrated
- 30% reduction in thermal load
- Potential for lower power A/C system or A/C used less often
- Reducing fuel use of vehicle air conditioning is within reach with current technology

Acknowledgements

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