MRI Mid-Year Trustees Meeting

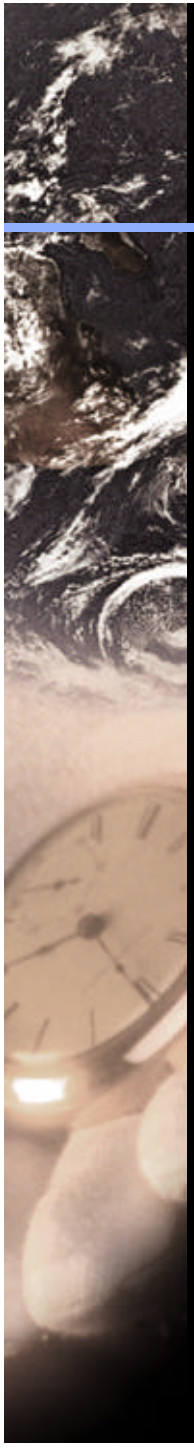
The Cool Car: Reducing Climate Control Loads in Vehicles

Time for World Class Solutions

National Renewable Energy Laboratory

Robert B. Farrington Ph.D., P.E

Center for Transportation Technologies and Systems



NREL Mission

Lead the nation toward a sustainable energy future by developing renewable energy technologies, improving energy efficiency, advancing related science and engineering, and facilitating commercialization

NREL Background

- Established in 1977 as Solar Energy Research Institute
- Current staff of approximately 800
- Operating budget of $173M for FY98

  (Approximately 50% of budget is contracted to industry and university research partners)

NREL Facilities

CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS

The CTTS Team

Center for Transportation Technologies and Systems

CTTS Programs

Director of the Center for Transportation Technologies and Systems
Barbara Goodman

Alternative Fuels Utilization Program

Hybrid Electric Vehicle Program

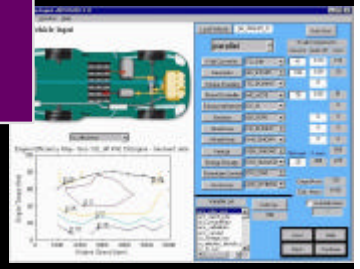
Heavy Vehicles

Business Leadership

Hybrid Vehicles

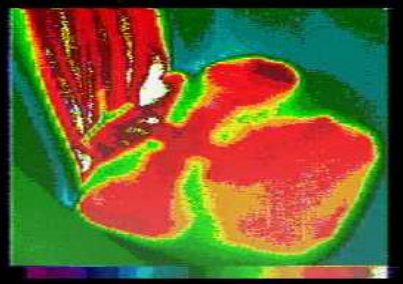
Alternative Fuels Analysis, Information, and Deployment

Advanced Automotive Systems

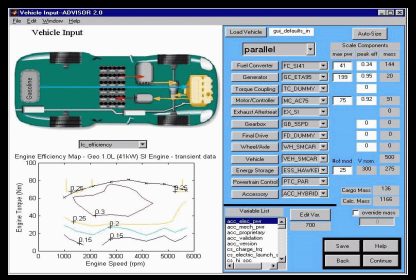


CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS

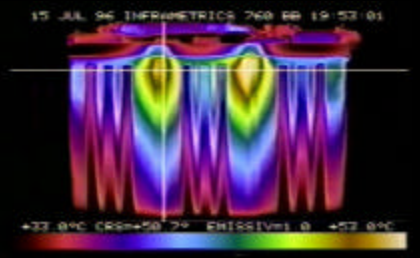
Hybrid Electric Vehicle Program



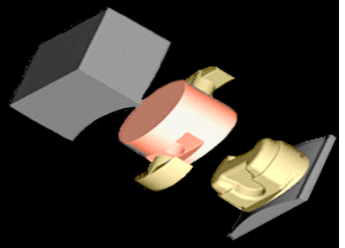
Vehicle Climate Control



Vehicle Systems Analysis



Battery Thermal Management



Vehicle Systems Virtual Prototyping

Big 3 Partnership

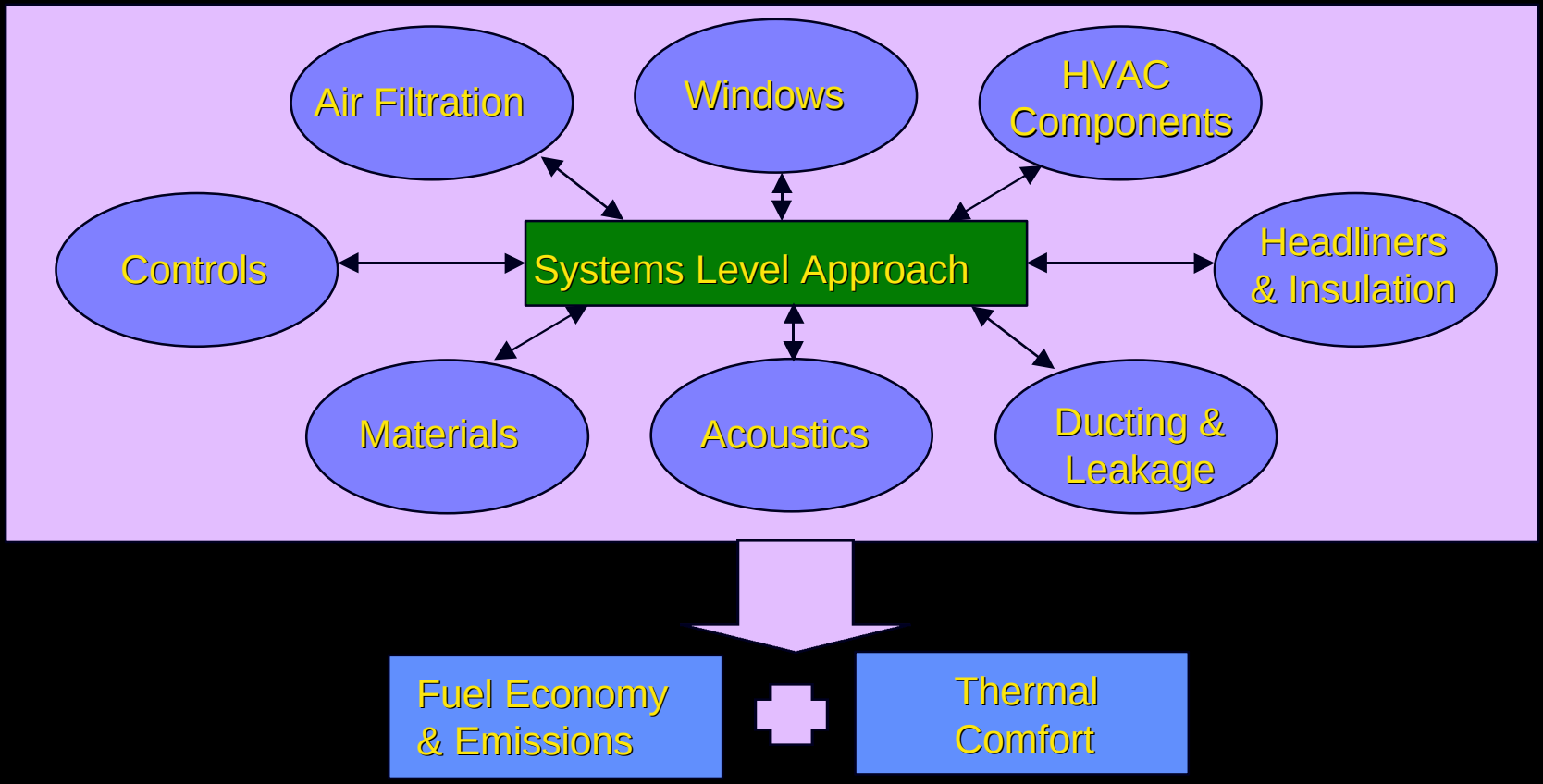
CENTER FOR TRANSPORTATION TECHNOLOGIES AND SYSTEMS

Cool Car Goal

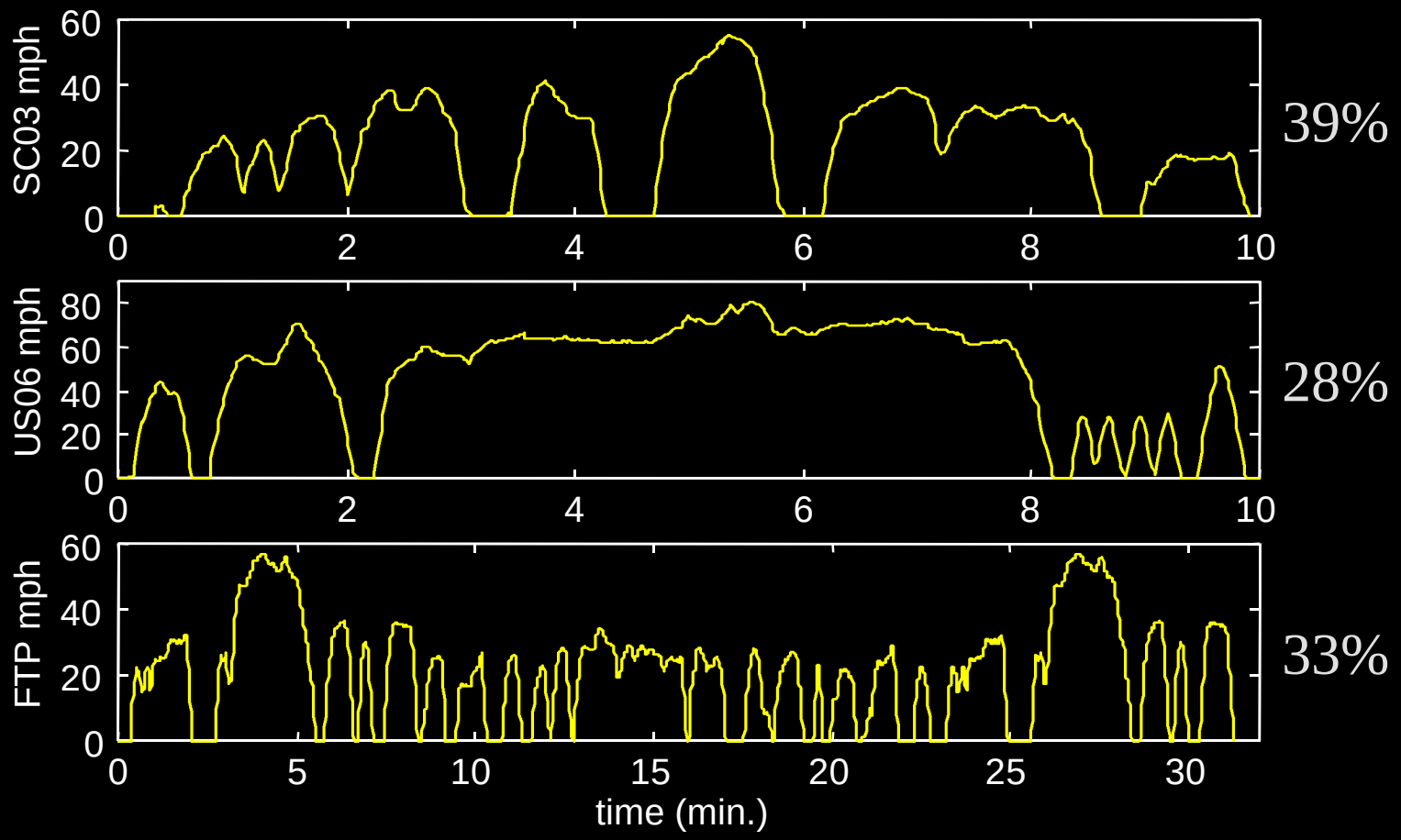
To reduce energy use for vehicle climate control by 50% while maintaining passenger thermal comfort and safety.

Our Approach

A systems approach to integrate components and systems to provide thermal comfort while reducing fuel consumption and emissions.



Supplemental Federal Test Procedure: Velocity Profiles



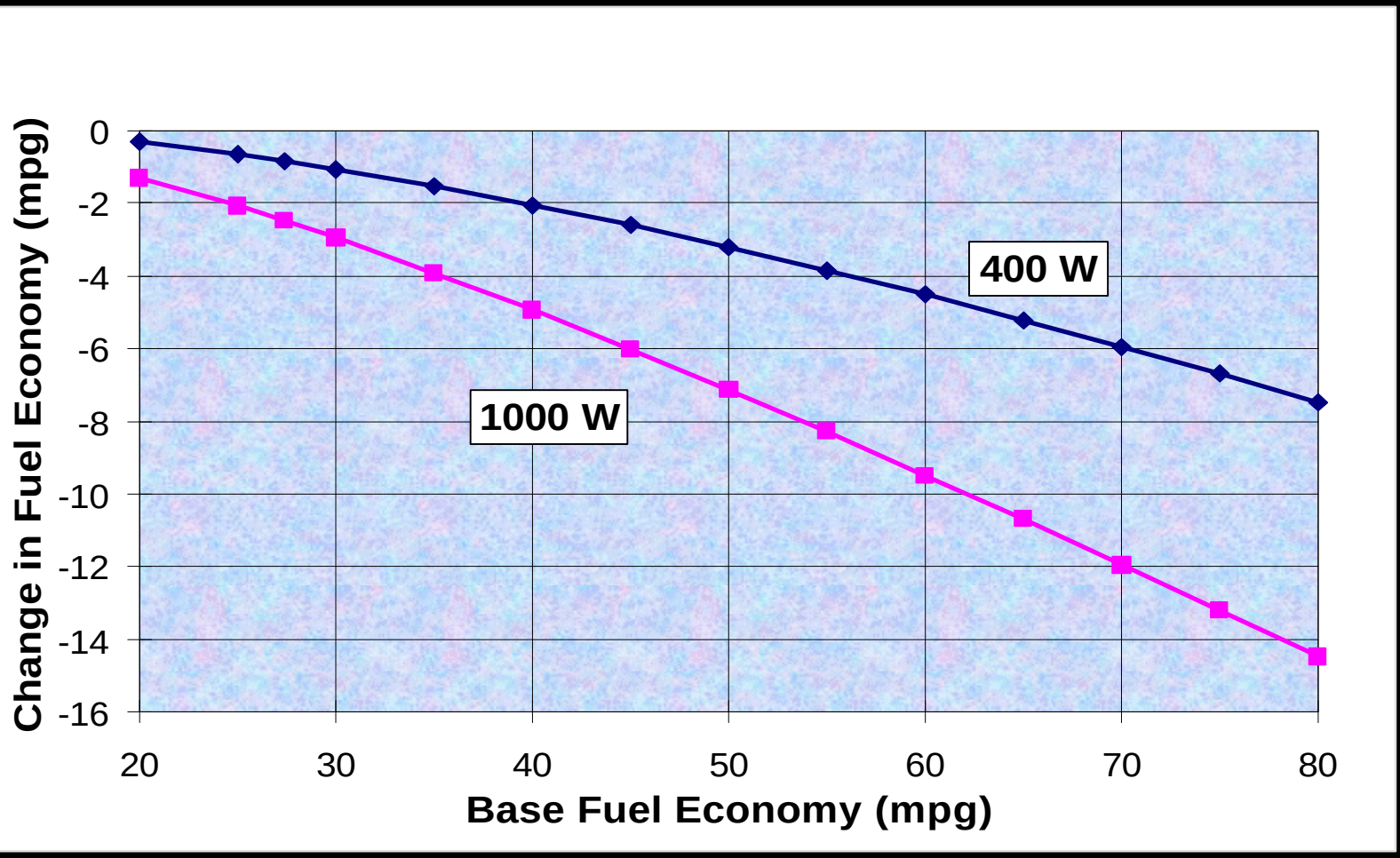
Supplemental Federal Test Procedure: Timeline

- MY 2000: 40% of manufacturer's fleet
- MY 2002: 80%
- MY 2004: 100%

-For cars & trucks under 6000 lb GVW
-Phase-in starts in MY2002 for 6001-8500 lb GVW

Source: John German (EPA-Ann Arbor)

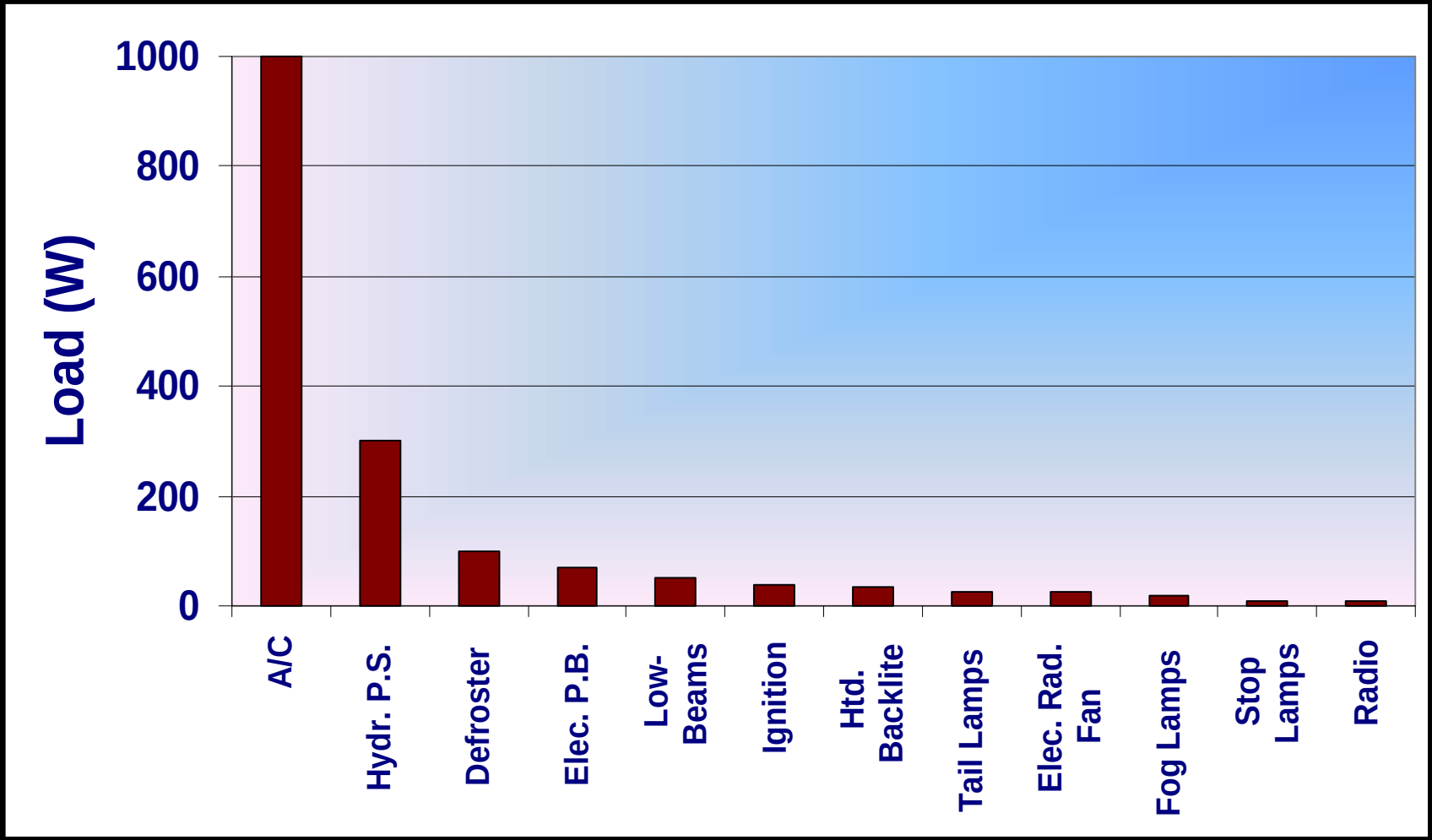
Fuel Economy Penalties From Auxiliary Loads



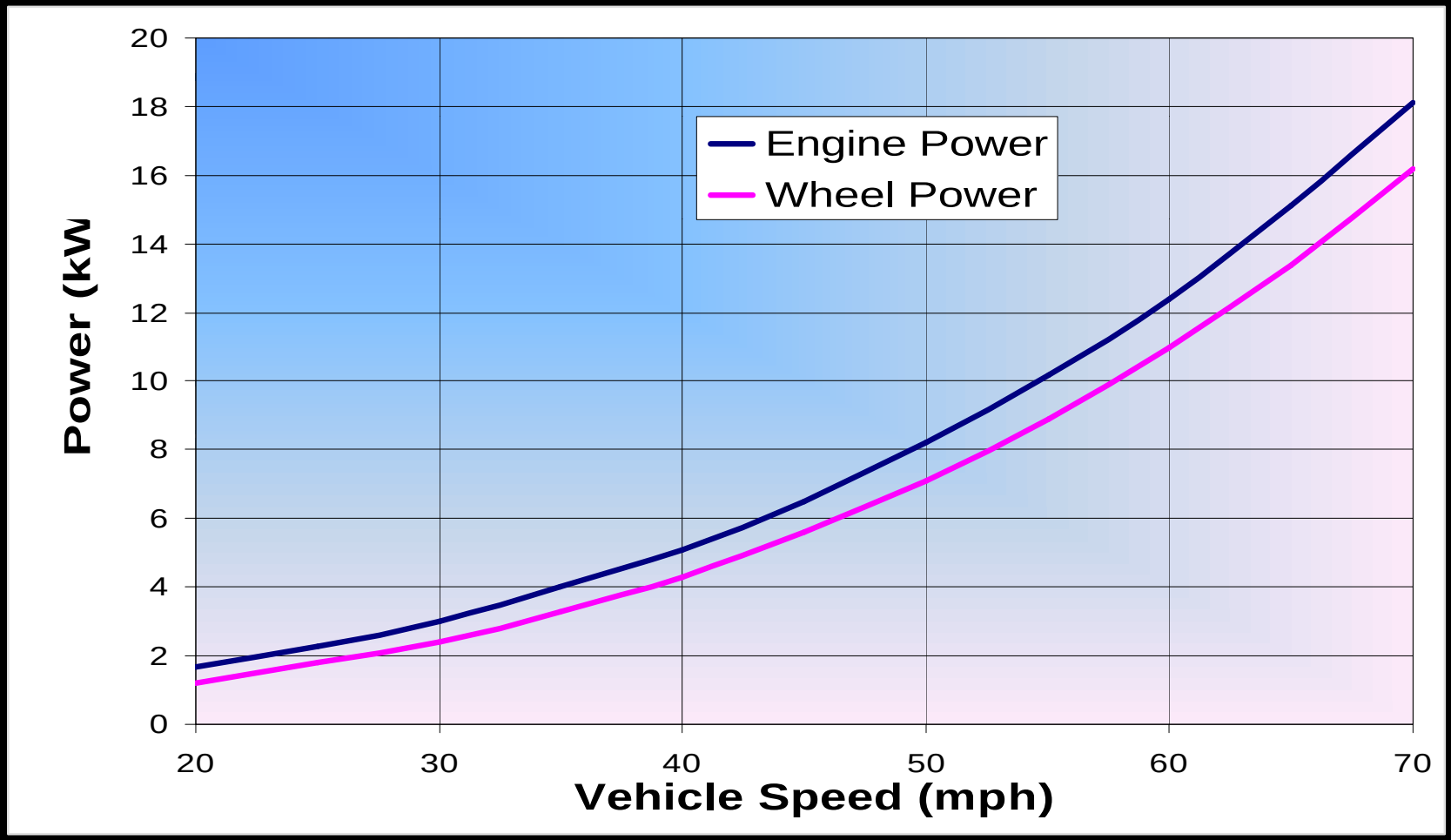
Reducing Vehicle Auxiliary Loads Saves Energy and Money

- MPG Effect
  - 400 W load on 40 mpg vehicles reduces fuel economy by 2.3 mpg
- $ Effect
  - 1 mpg increase saves $4 billion/yr nationally
  - Consumers spent $104 billion on fuel and oil, 1993
  - 5% reduction in fuel consumption => $5 billion/yr and 127M barrels/yr.

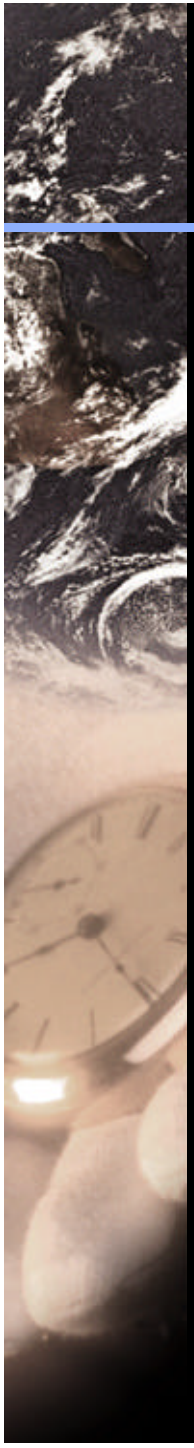
Average Accessory Loads



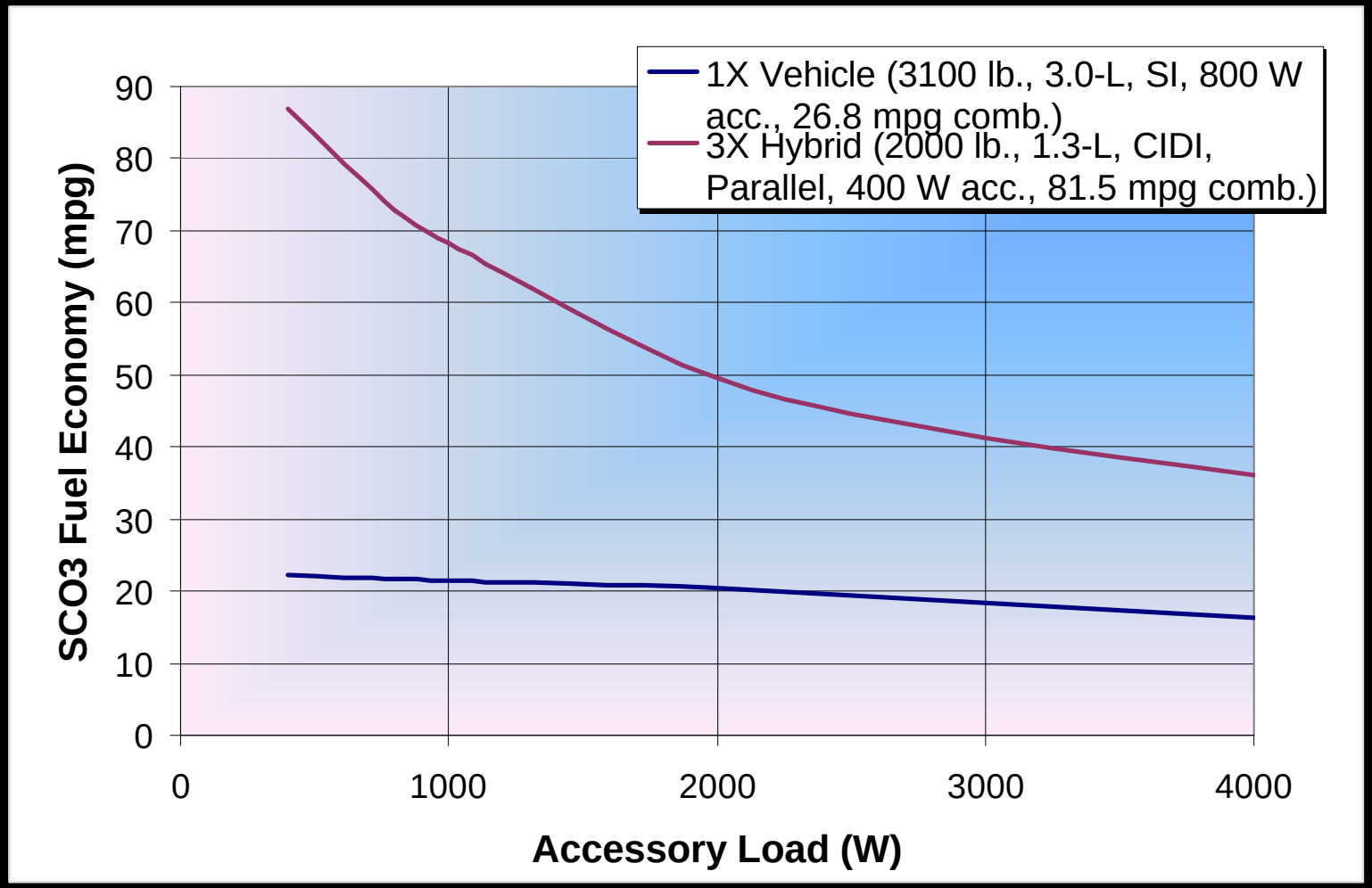
Power vs. Vehicle Speed



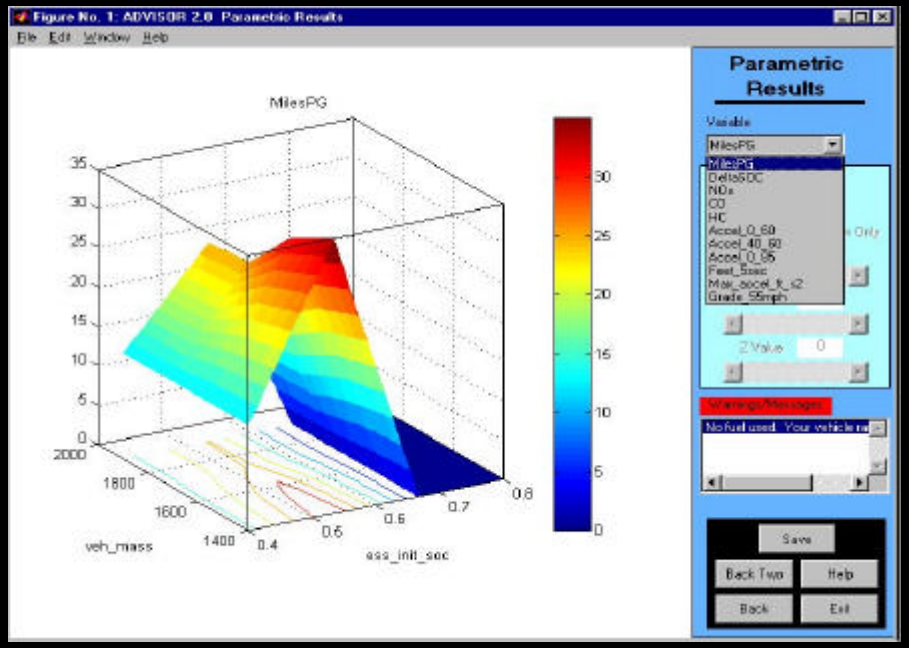
A/C Increases Engine Loading



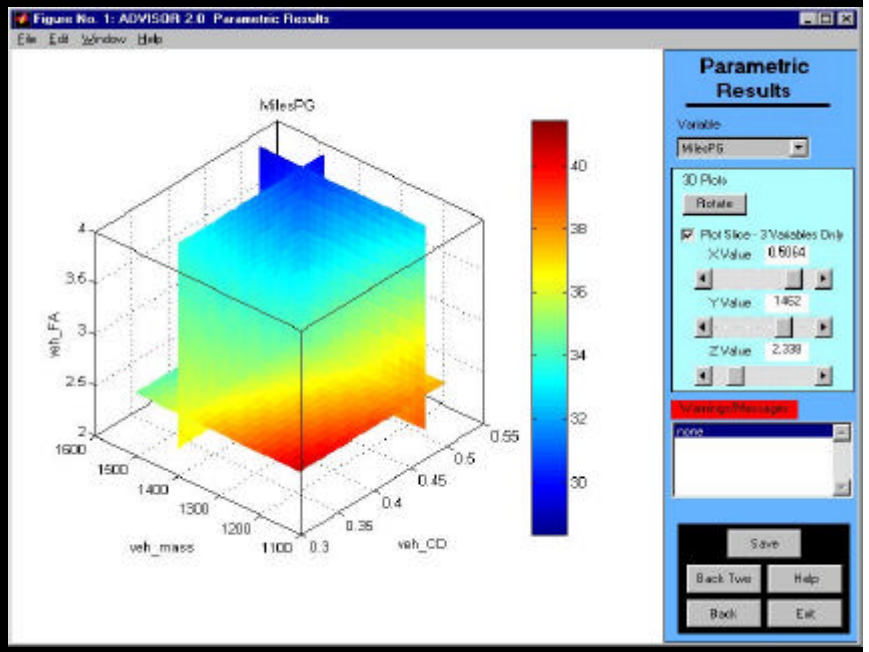
Fuel Economy Impact



Parametric Results



2 Variable Parametric Study

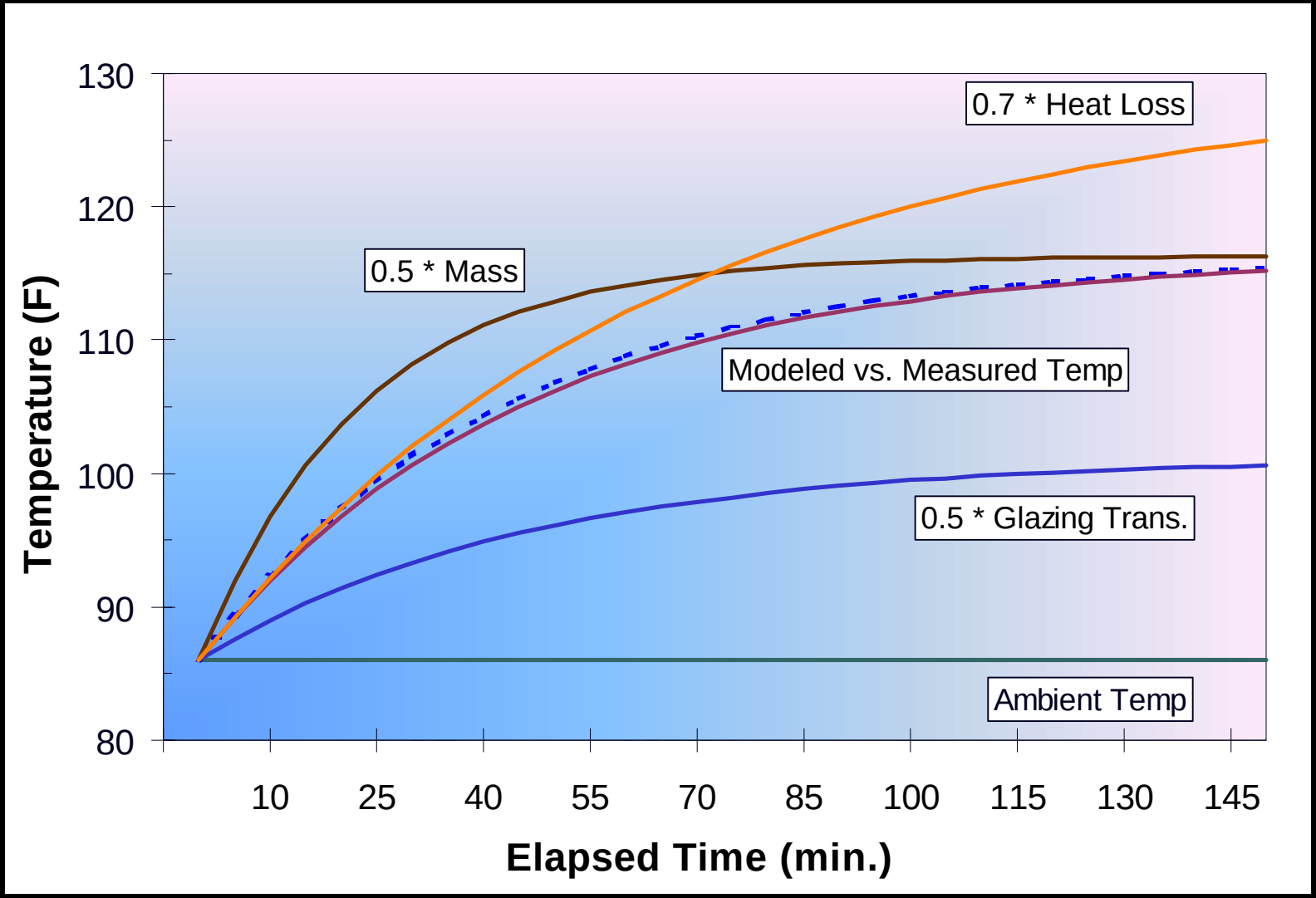


3 Variable Parametric Study

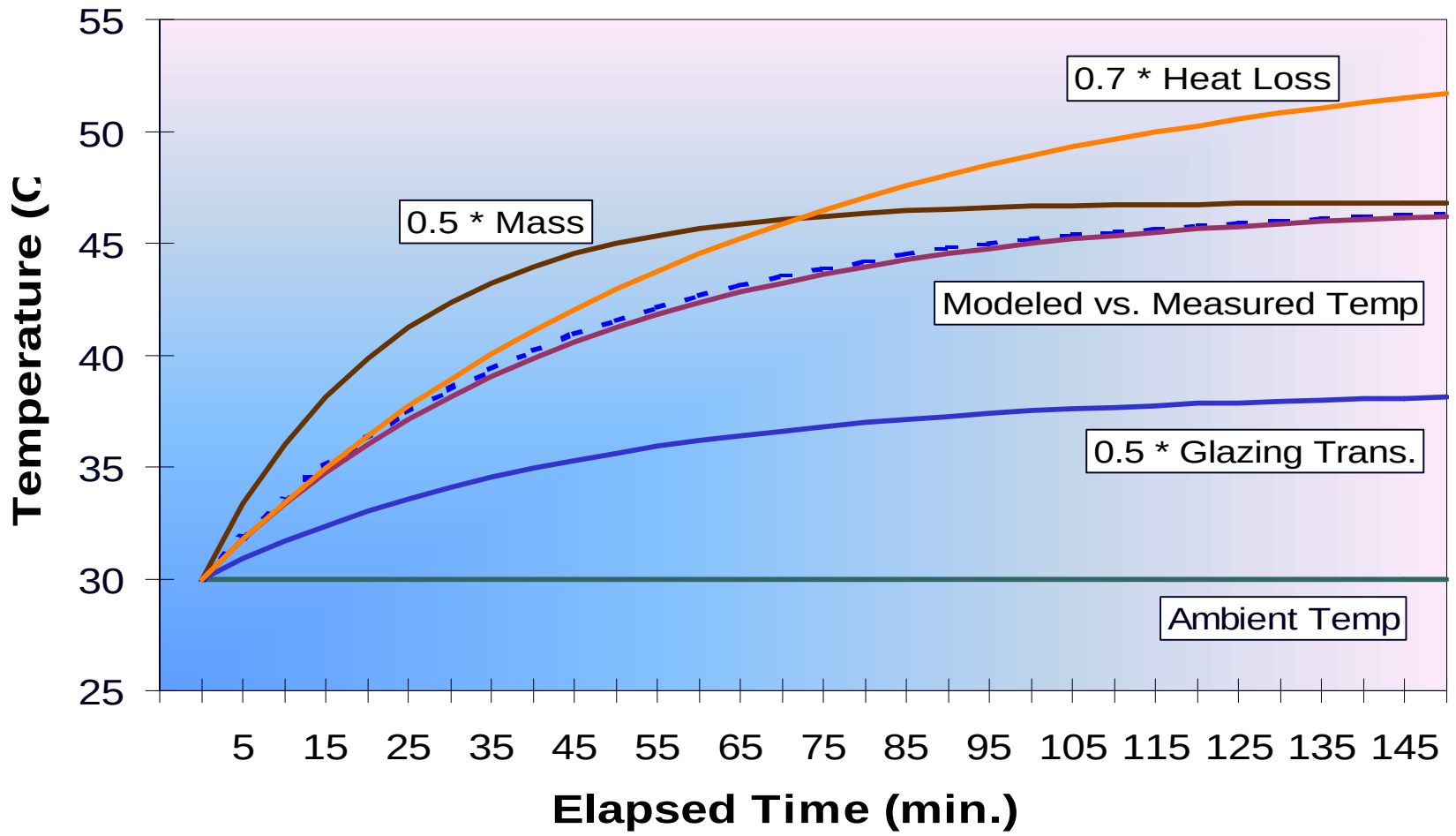
Benefits of Cool Interiors

- Higher fuel economy
- Reduced emissions
- Greater initial occupant comfort
- Less harsh interior materials environment
- Driver safety - alertness, cooler surfaces

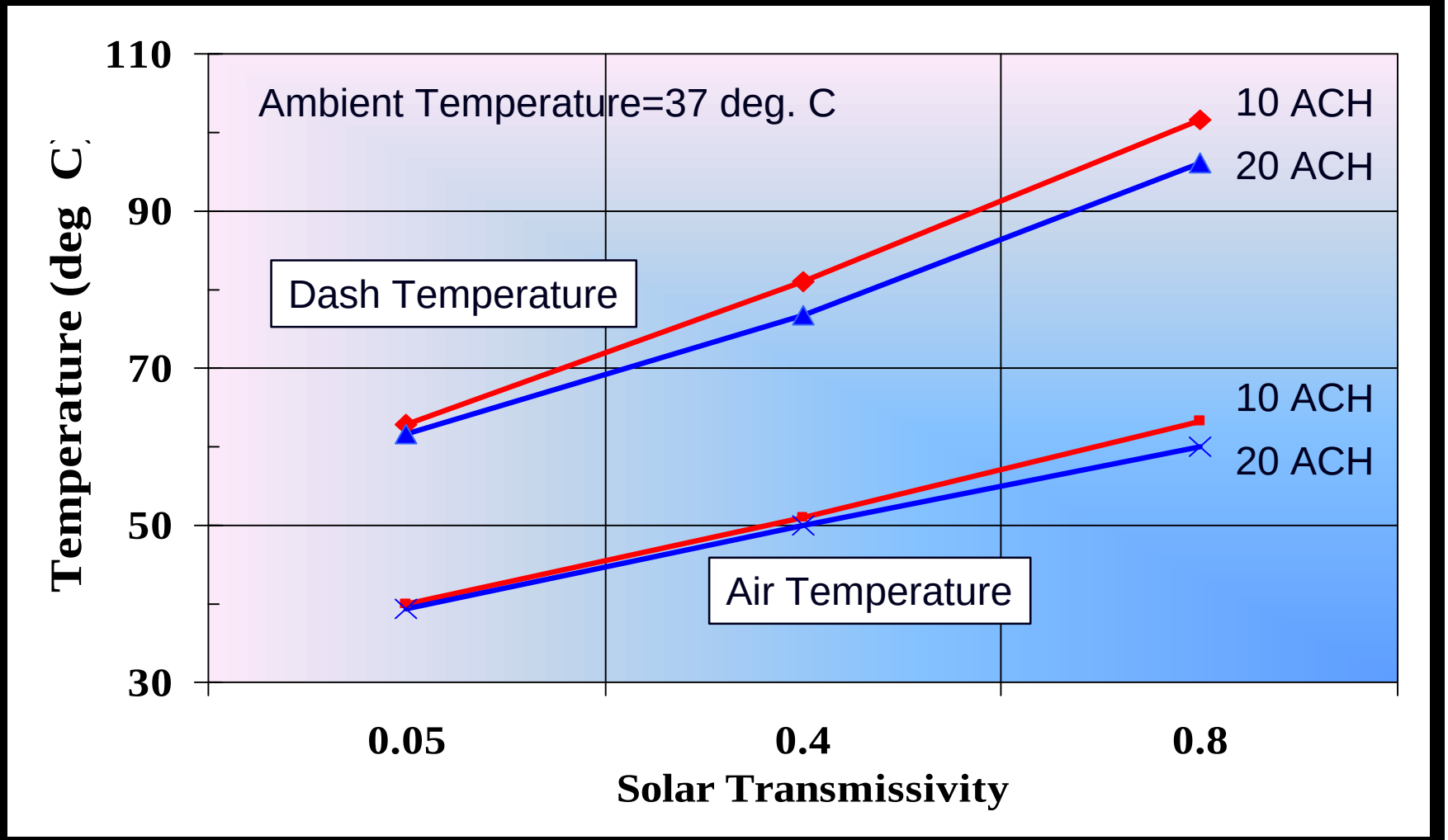
Soak Temperature Sensitivity



Soak Temperature Sensitivity



Predicted Peak Dash/Air Temps.



NREL's Breeze Test Vehicle

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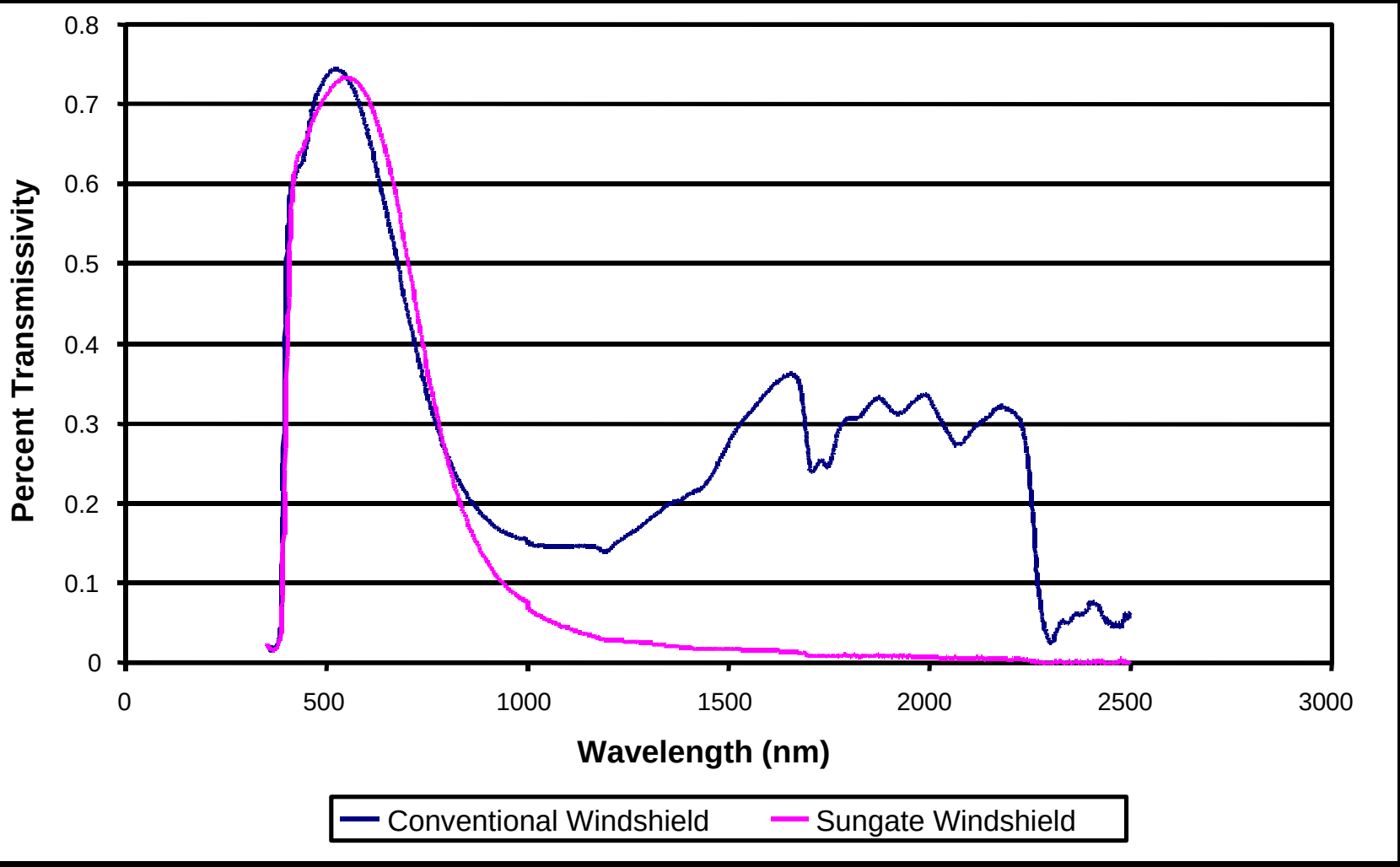
Solar Gain Reducing Windshields

NREL tested 3 different windshields:

- Sungate
- Solex
- Solar green

Sungate Windshield Description

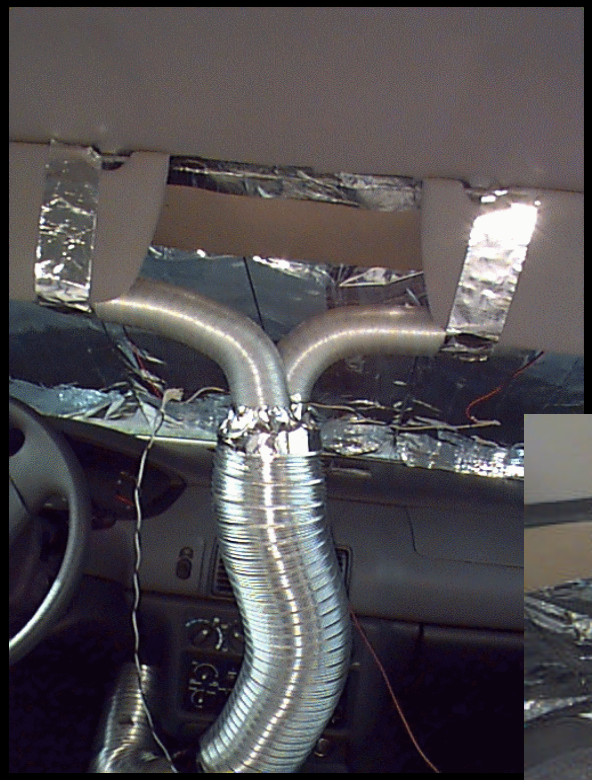
Solar Reflective Windshield



Fuel Economy Results
(assuming a compressor efficiency of 75%)

Windshield	Mechanical Accessory Load (kW/hp)	SFTP		SCO3 Only	
		Fuel Econ. (mpg)	% Change from Solex Baseline	Fuel Econ. (mpg)	% Change from Solex Baseline
Solex®	3.9/5.2	26.2	--	20.4	--
Sungate®	3.5/4.7	26.7	1.7%	21.1	3.4%

Boundary Layer Technique

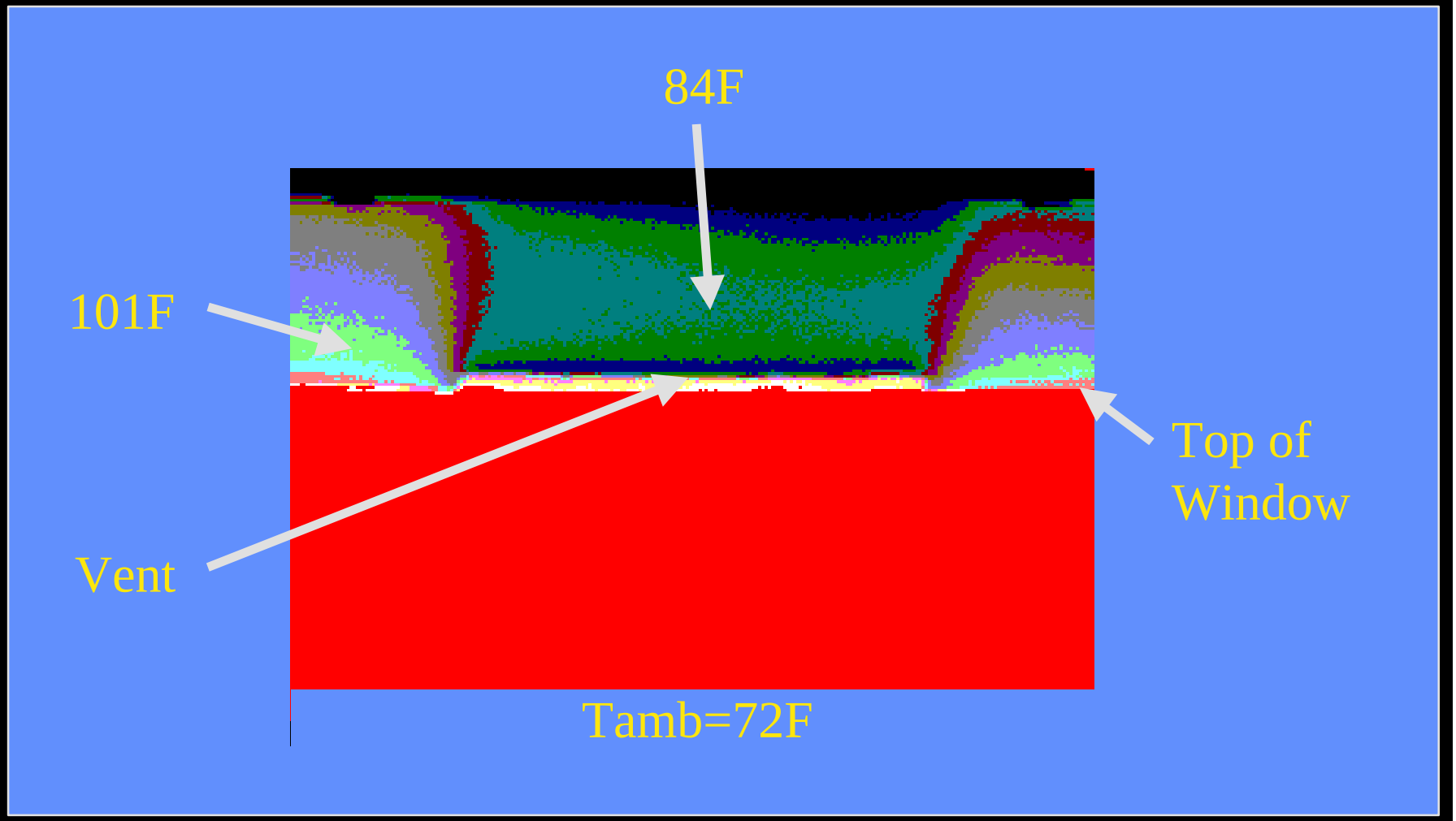


Testing set-up inside the Neon

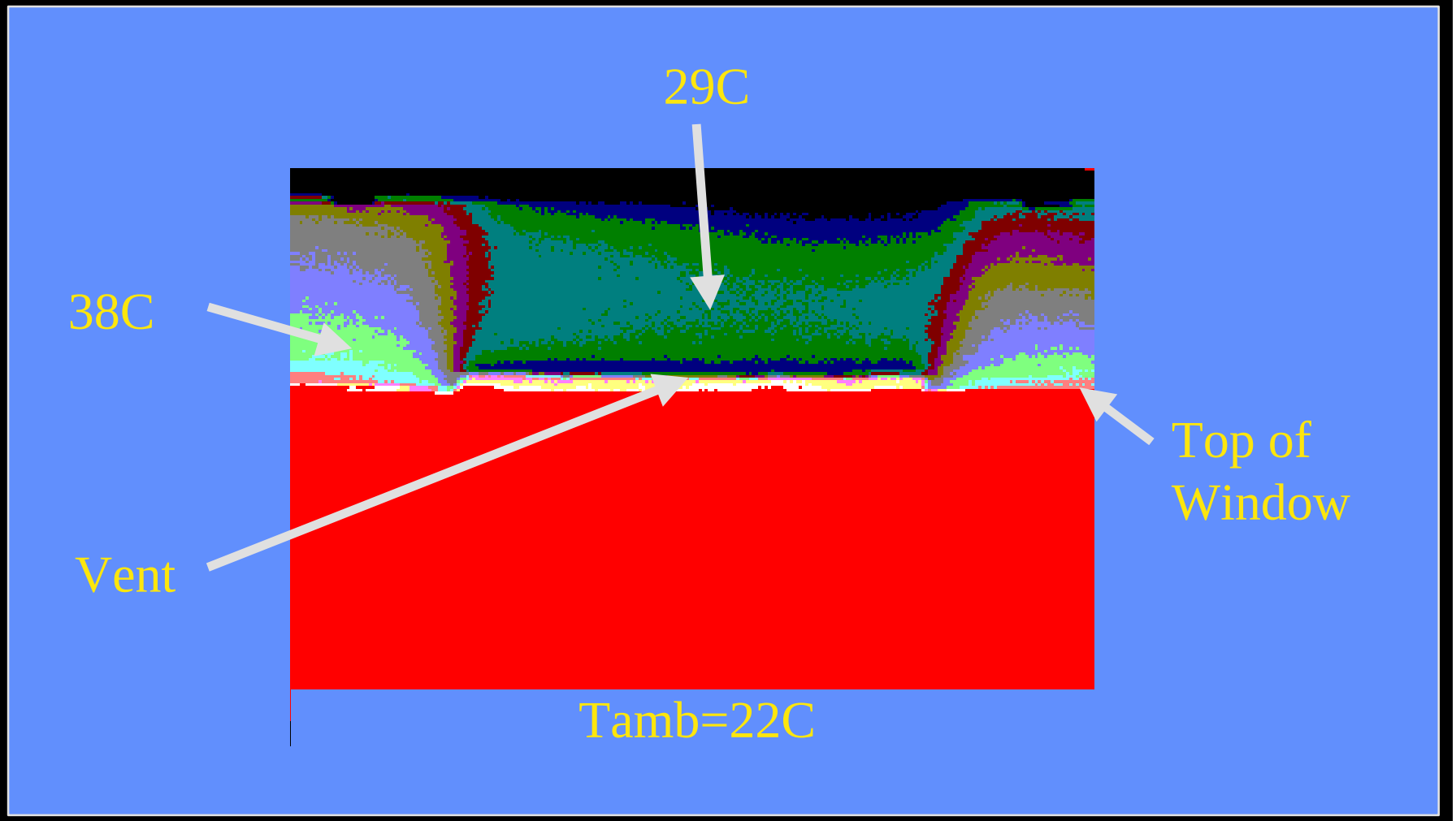
NREL is evaluating how the hot boundary layer that forms along windows inside a vehicle can be effectively removed.

Boundary Layer Mockup

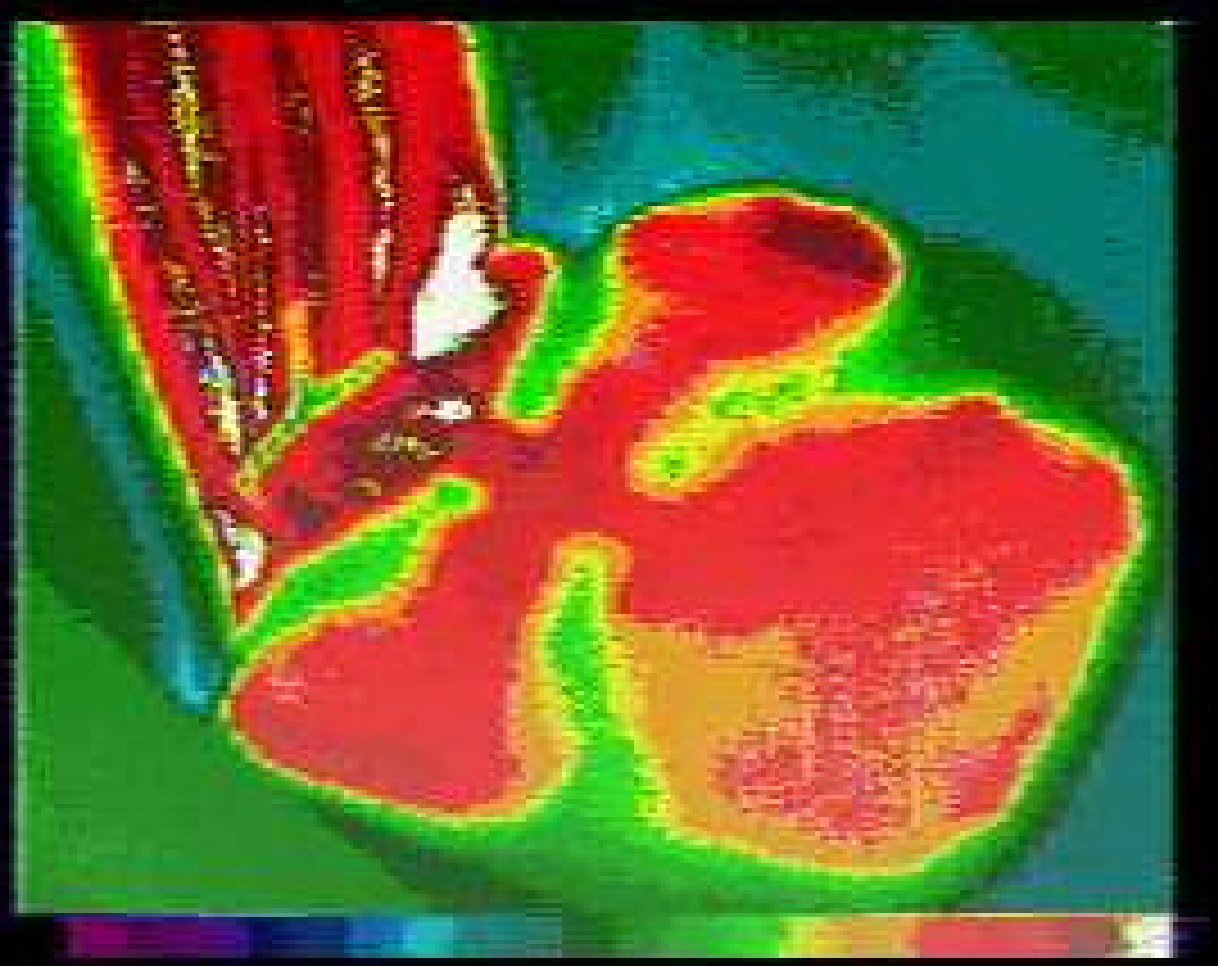
Impact of BL Control on Local Surface Temperature



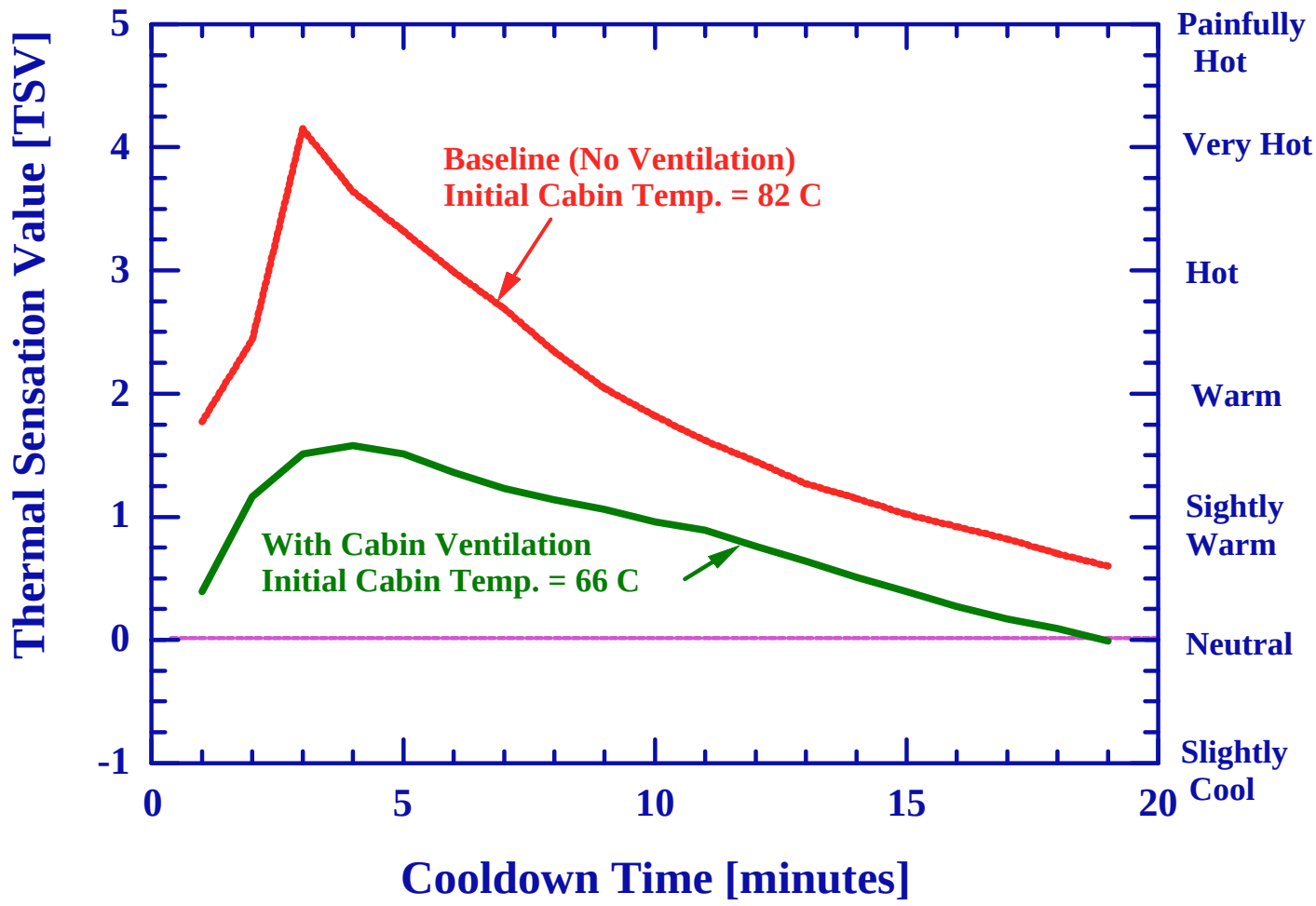
Impact of BL Control on Local Surface Temperature



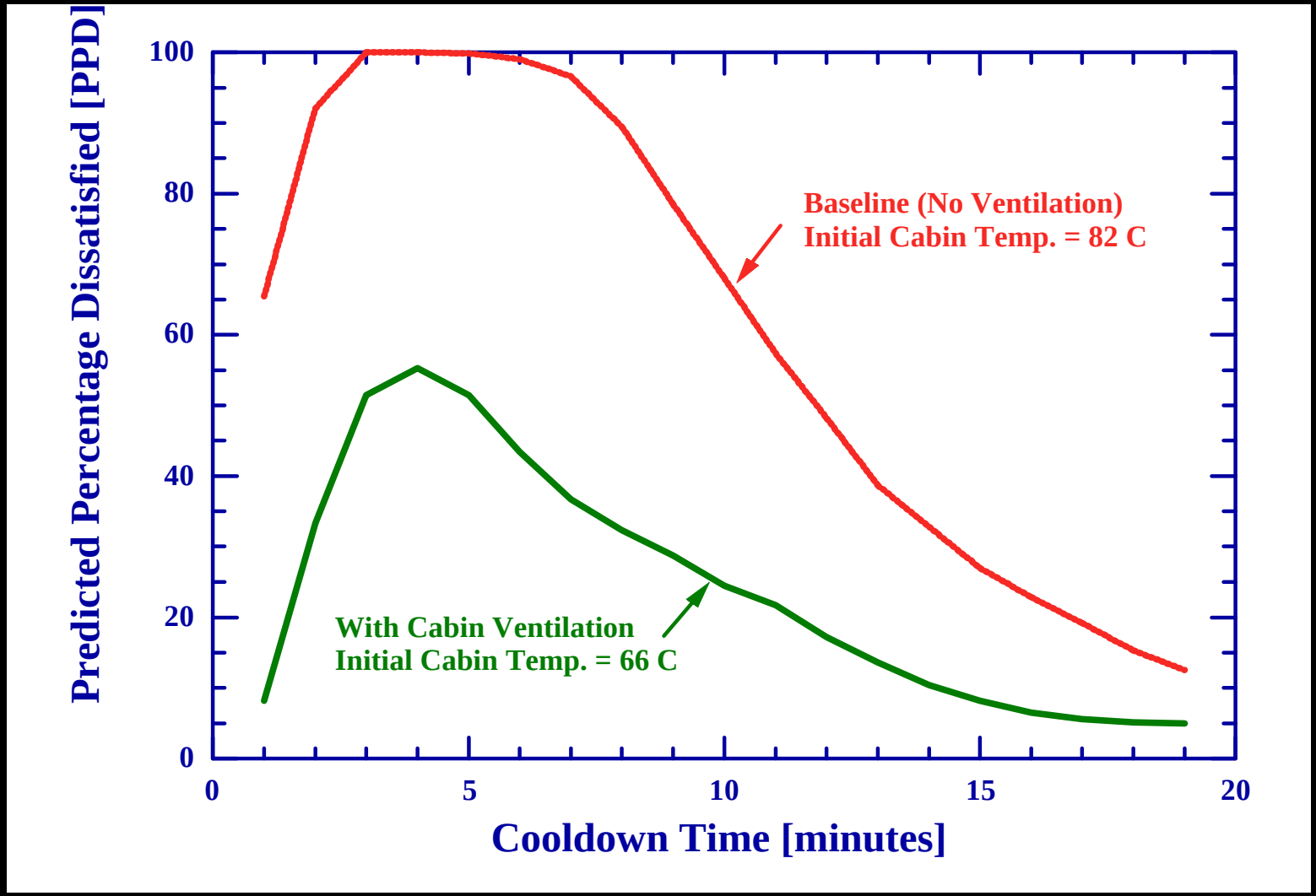
Infrared Image of Heated Seat



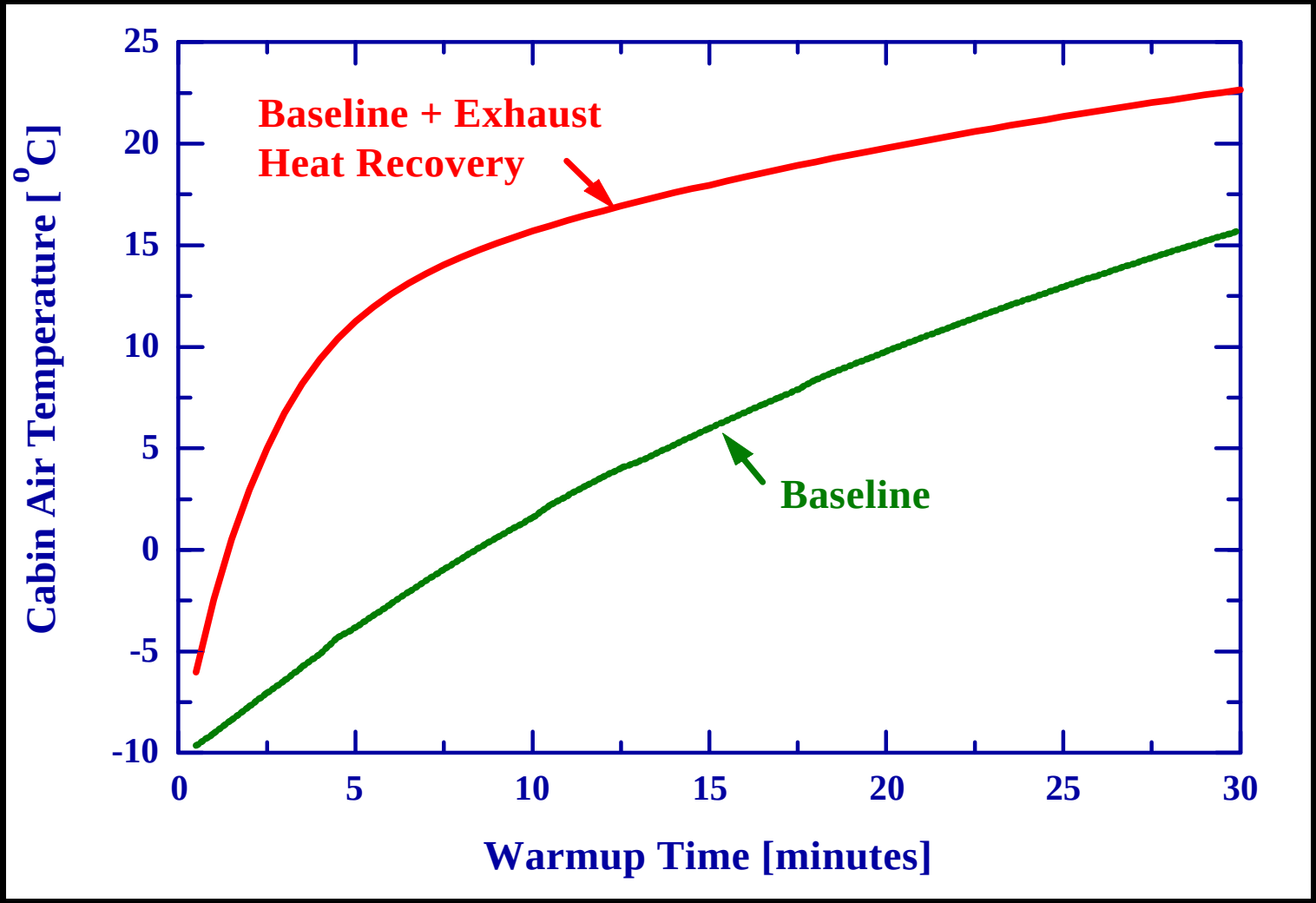
Thermal Comfort - TSV



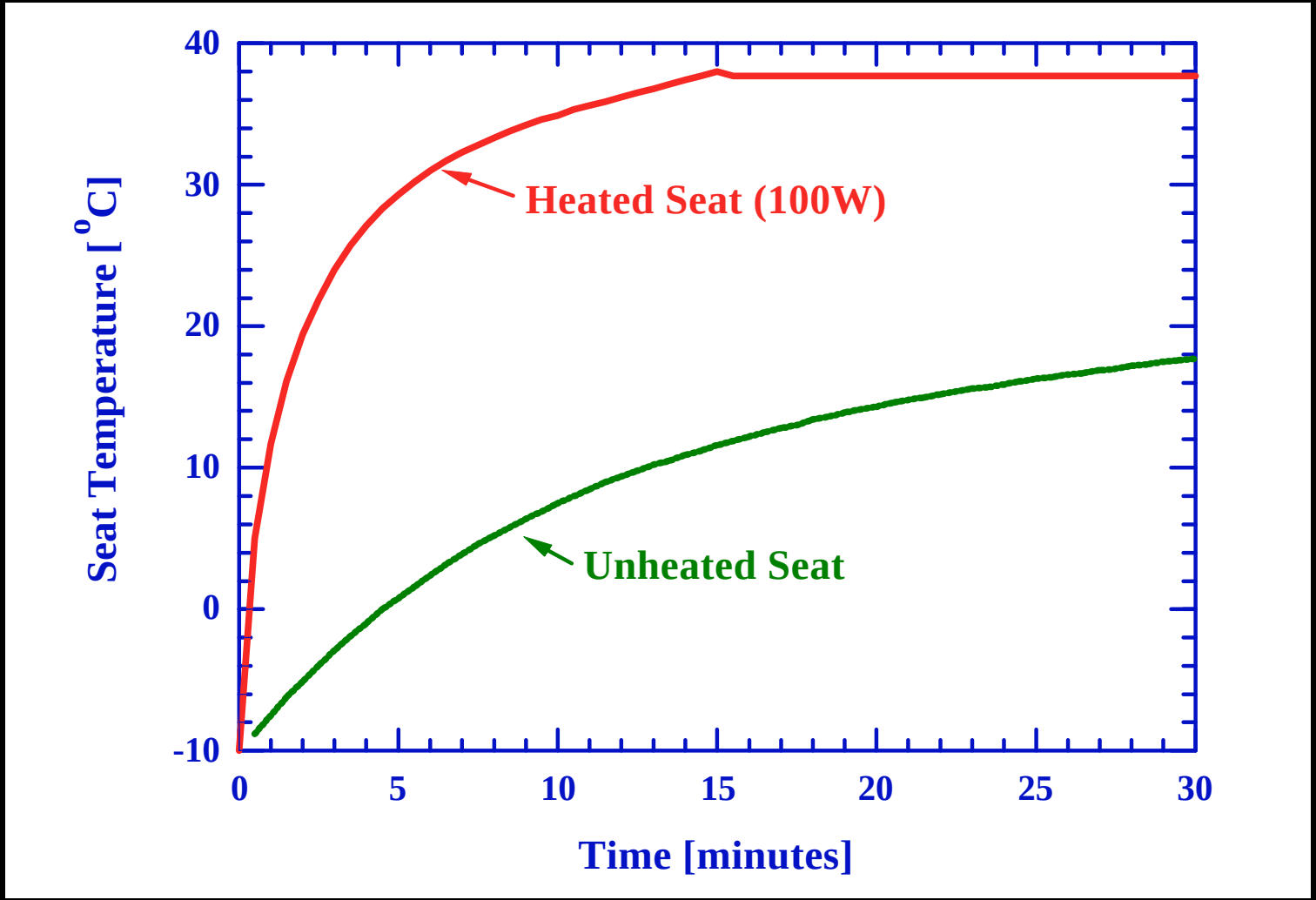
Thermal Comfort - PPD



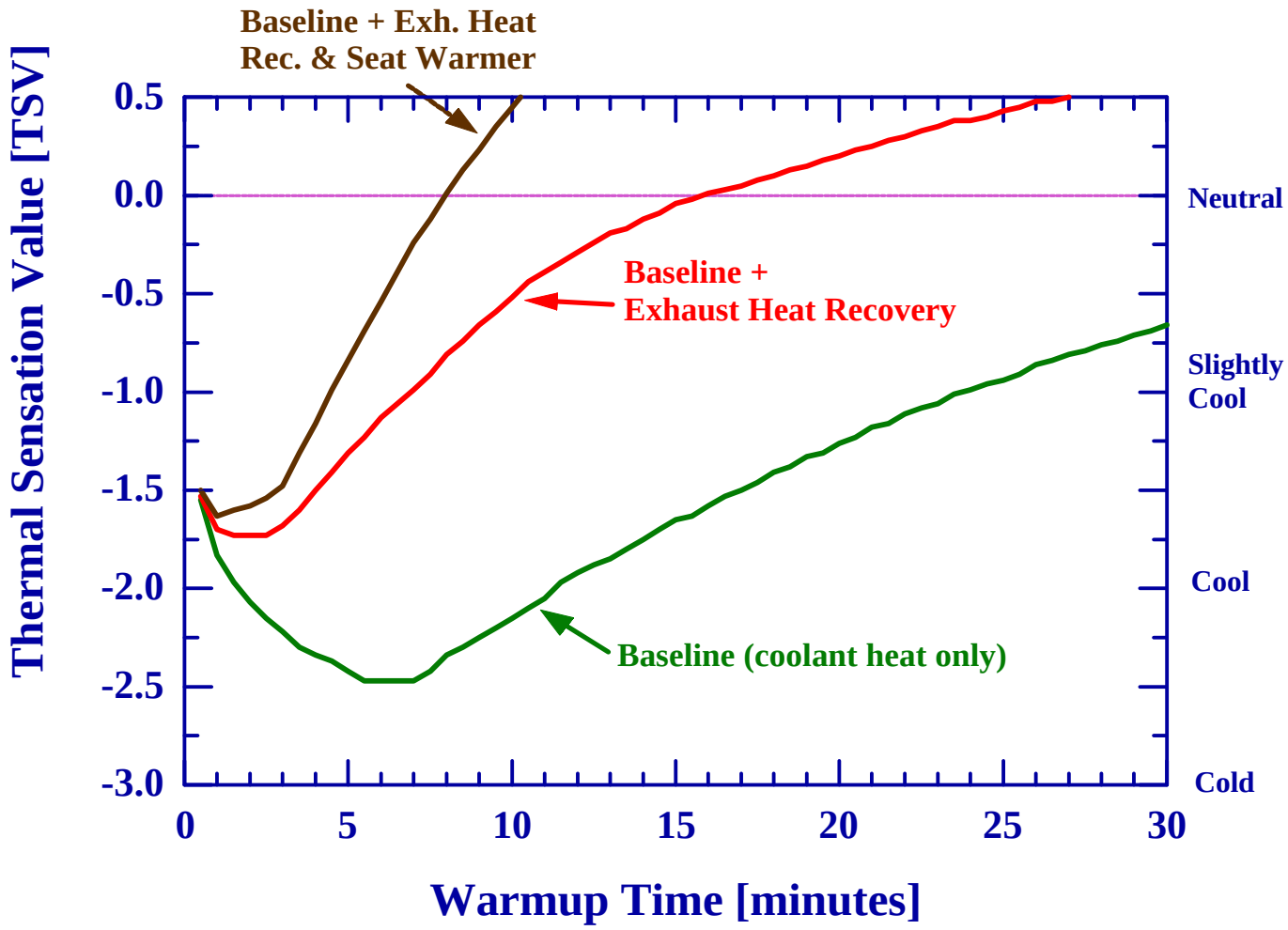
Cabin Warm-up: Exhaust Heat



Cabin Warm-up: Heated Seat



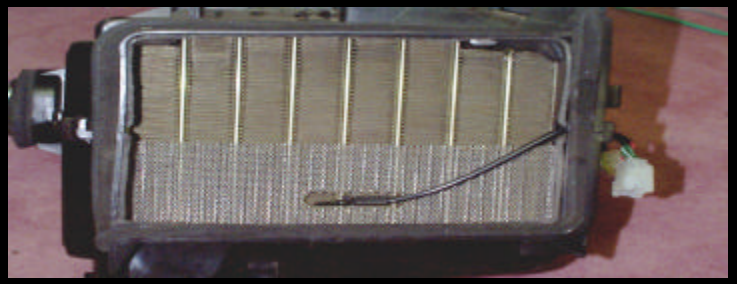
Cabin Warm-up: TSV



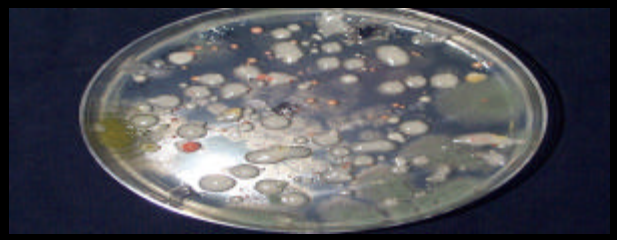
Cabin Air Cleaning Options

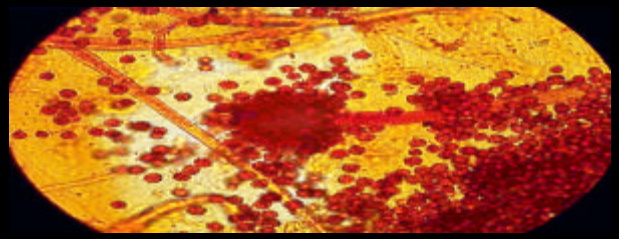
- Ventilation
- Activated carbon unit (requires regeneration or periodic replacement)
- Photocatalytic device (alone or in combination with activated carbon)
- Other chemical or photochemical treatment methods (ozone, catalytic oxidation, etc.)

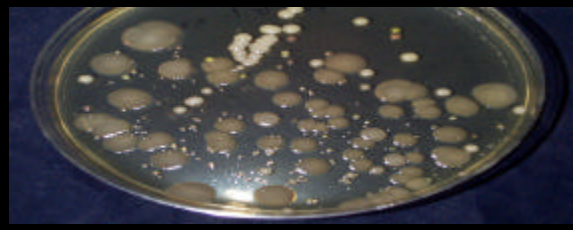
Microbial Examination of A/C System (Chrysler 1990)



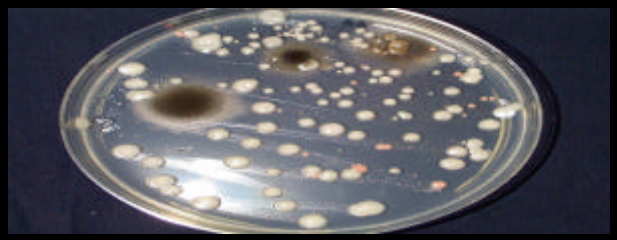
Evaporator

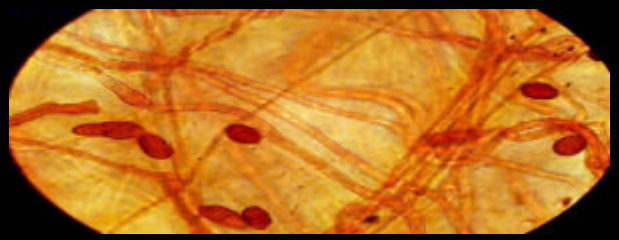






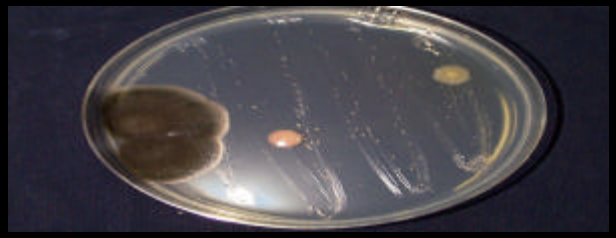
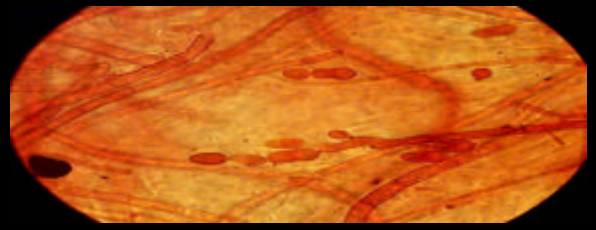
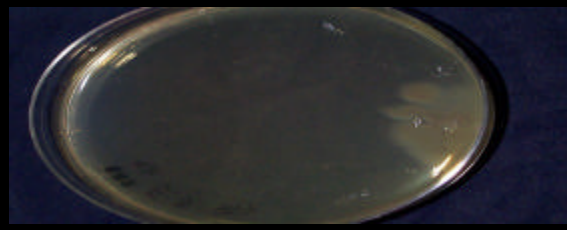
Fungal growth from evaporator A - swab sample



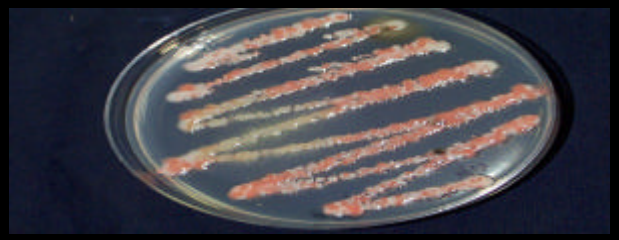


From evaporator B

Microbial Examination of A/C System (Chrysler 1990)

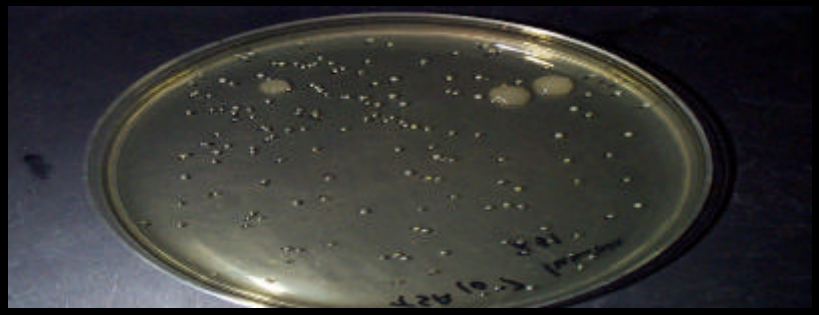




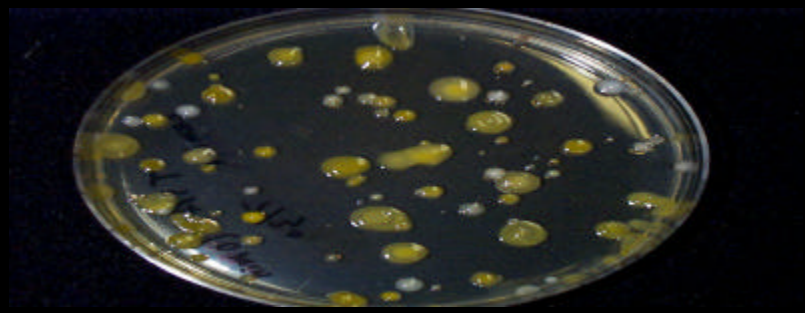
From evaporator C

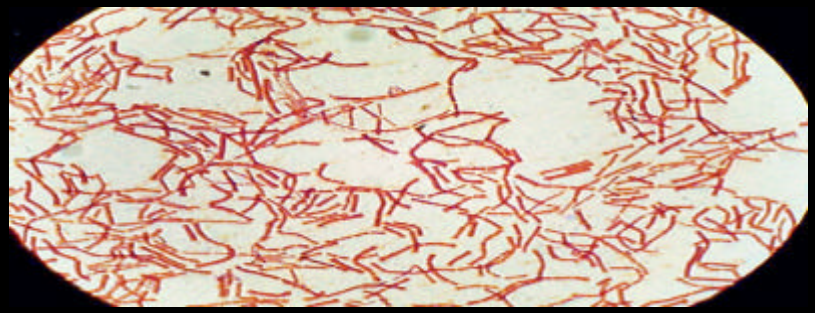


From evaporator E

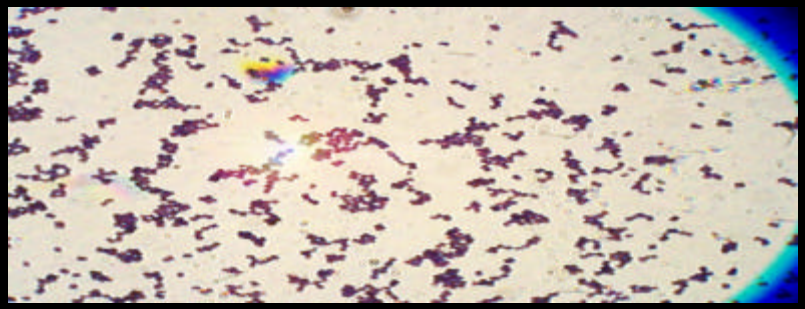
Microbial Examination of A/C System (‘96 Lumina)



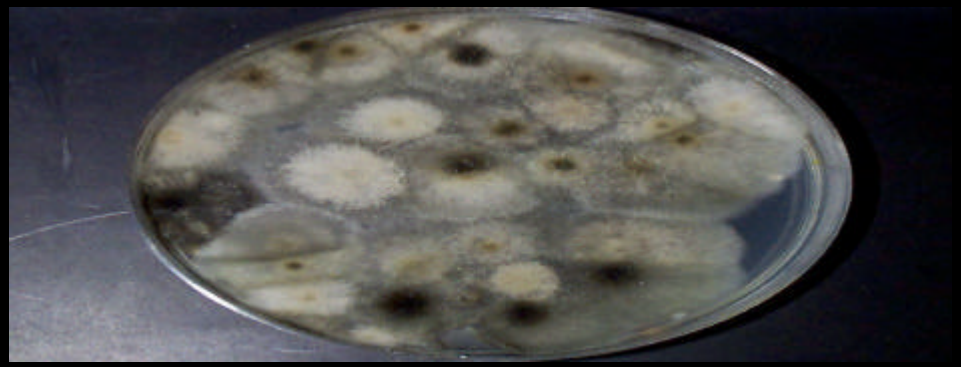




Bacterial growth from A/C vent swab sample



Outflow from A/C vent (10 min exposure)



Fungal growth from A/C vent (10 min exposure)

Objectives for Integrating Photocatalytic Oxidation (PCO) Unit into a Vehicle

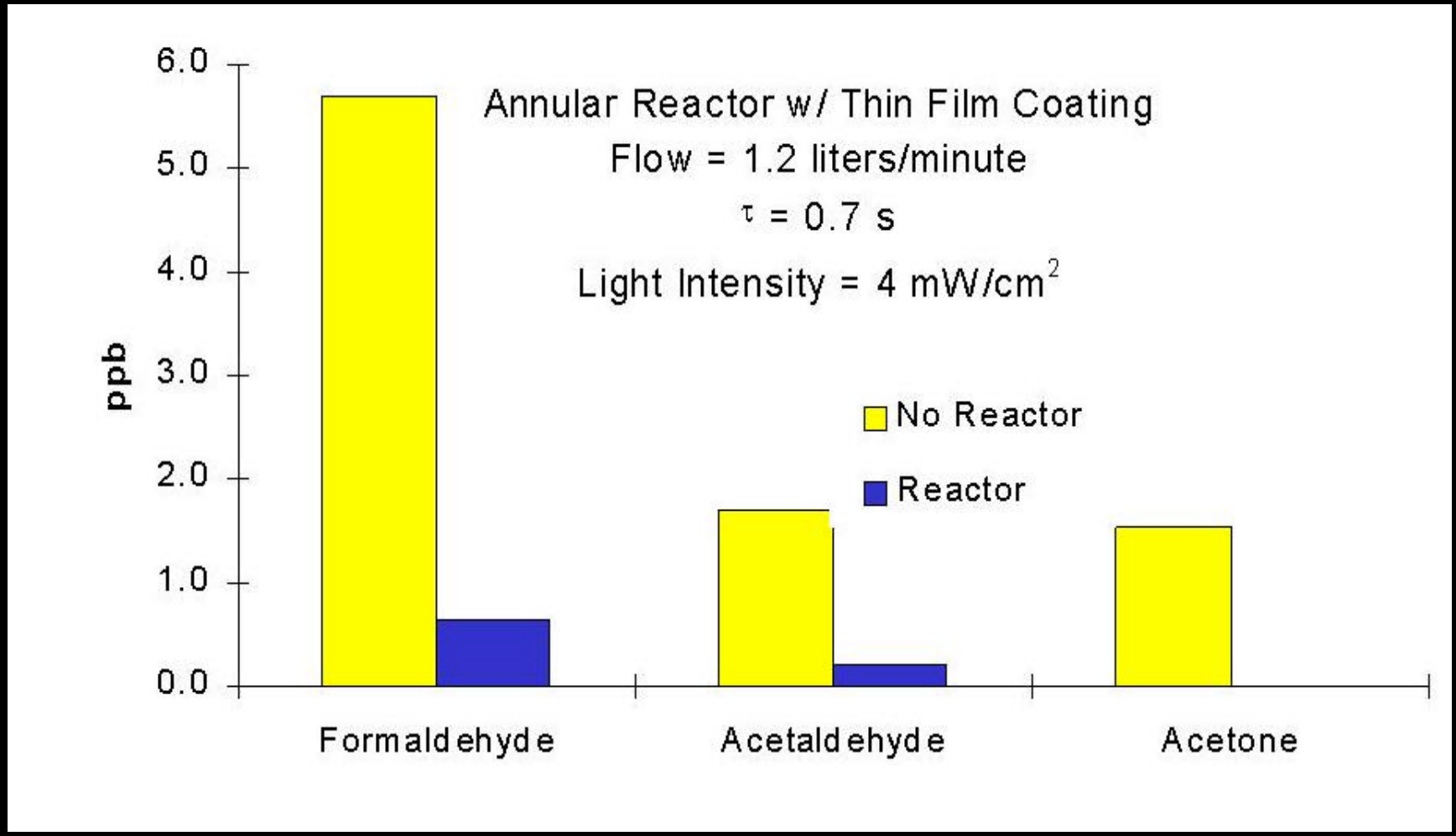
- Simple unit that can be integrated into the HVAC assembly
- Power consumption less than 10 watts
- Unit cost less than $10
- Capable of removing VOC's from fuels, vehicle emissions, odors, and interior materials
- Can increase use of recirculated air

Advantages of PCO System

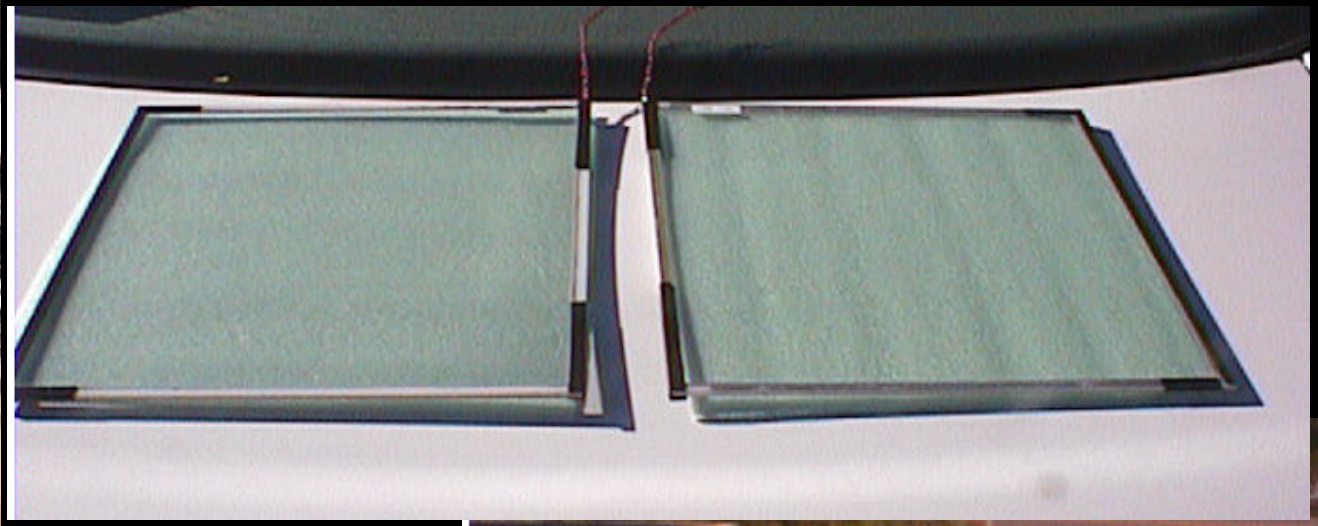
- Acts as a self cleaning filter for VOCs and bioaerosols
- Low maintenance - light bulb and catalyst/filter media (project long life unless it becomes contaminated with inorganic matter)
- Operates at ambient conditions - insensitive to temperature, 0 - 82 C

NREL's PCO Device

PCO Performance



Electrochromic Sunroof



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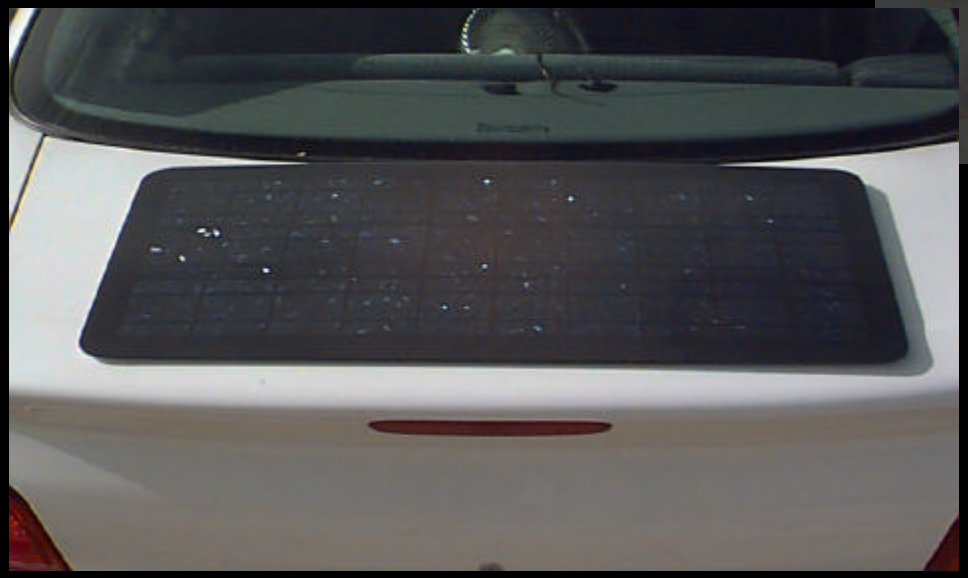
PV Sunroof - Trunk Mounted

- Aperture Area = .37 m^2
- Pmax = 30W
- Efficiency = 8%



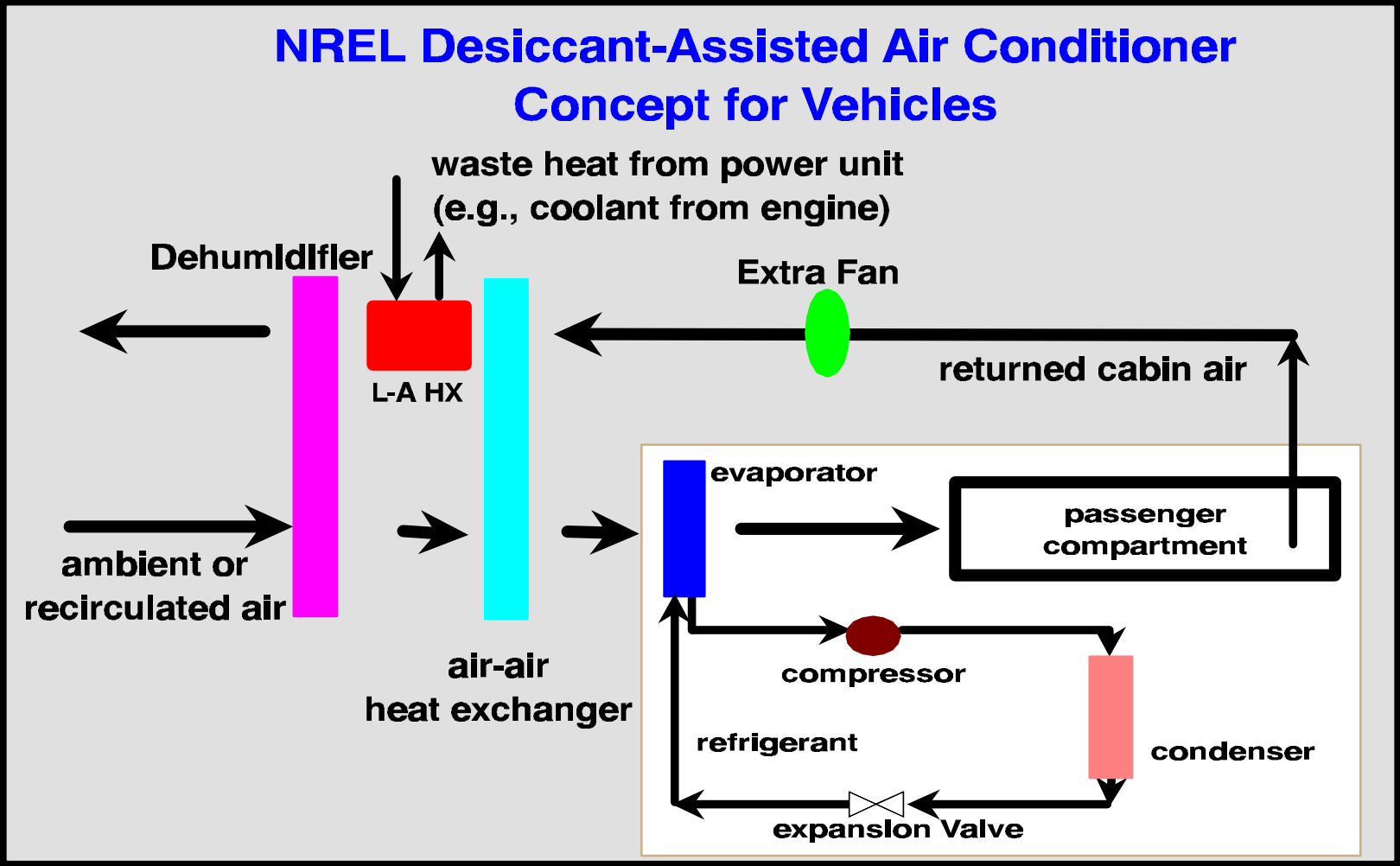
Desiccant-Assisted A/C

- **Advantages**
  - Efficient latent load removal
  - Improved cabin comfort because of lower humidity
  - Potential for reducing AC components size (30% less compressor power required)
  - Use of waste heat, lower overall fuel consumption
  - Potential for more efficient defrost/defog

Desiccant-Assisted A/C

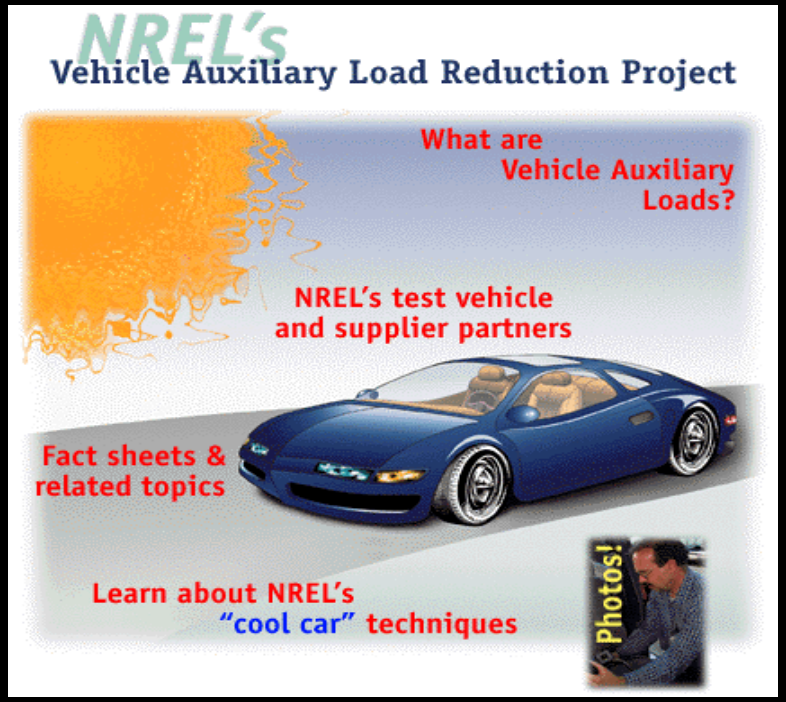
- Disadvantages
  - More components
  - Increased mass (about 3 kg)
  - Complexity in packaging and control

Desiccant-Assisted A/C Schematic



NREL's Cool Car Web Site

To learn about NREL's Vehicle Auxiliary Load Reduction Program, go to the "cool car" Web site.

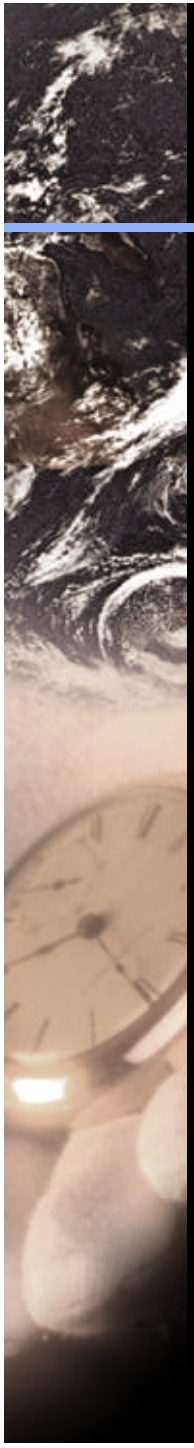


The address is:

http://www.ctts.nrel.gov/auxload.html

Or contact Rob Farrington, project manager, at (303) 275-4448

Center for Transportation Technologies and Systems



Acknowledgments

- Ren Anderson, Thermal Analysis and Testing
- Dave Benson, Electrochromic Windows and Energy Storage
- Dan Blake, Photocatalysis
- Debbie Brodt-Giles, Technical Communications
- Jay Burch, Thermal Modeling
- Nick Chornet, Photocatalysis
- Matt Cuddy, Thermal Analysis and Modeling
- Sara Farrar, Thermal Comfort Modeling
- Bill Jacoby, Photocatalysis
- Matt Keyser, Vehicle Testing
- Terry Penney, Industry Liaison
- Ahmad Pesaran, Desiccant Technology
- Cassie Quaintance, Cabin Thermal Modeling
- Loreno Roybal, Photovoltaics
- Tom Thoensen, Vehicle and Subsystem Testing

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