# MICROCLIMATE COOLING

## Chemical Biological Individual Protection Conference

## 7-9 March 2006

U.S. Army Natick Soldier Center
Individual Protection Directorate

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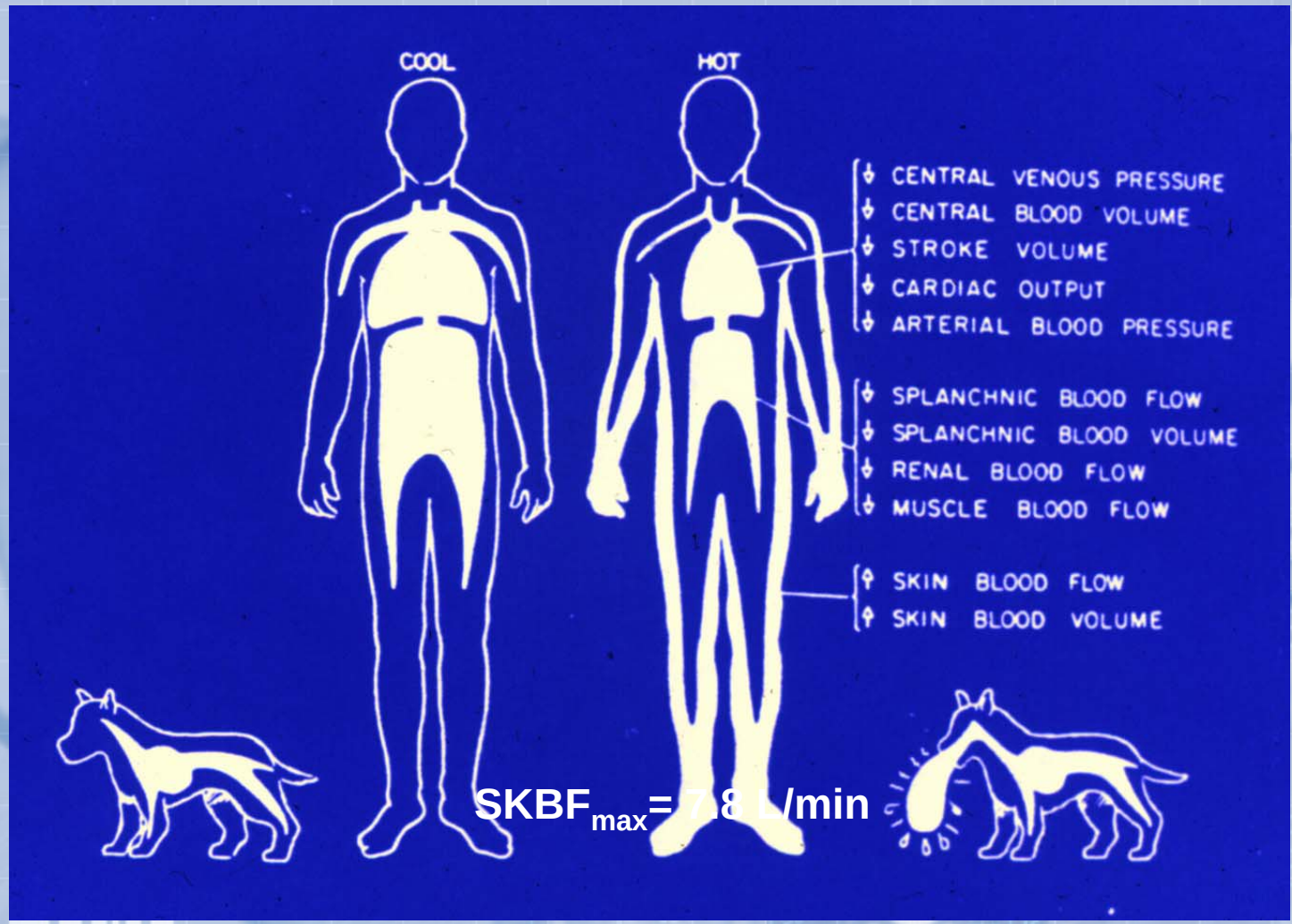
# Warfighter Microclimate Cooling
# The Need

A Warfighter working at a moderate activity level, in MOPP IV in a warm/hot environment will succumb to heat stress in 60-90 minutes.

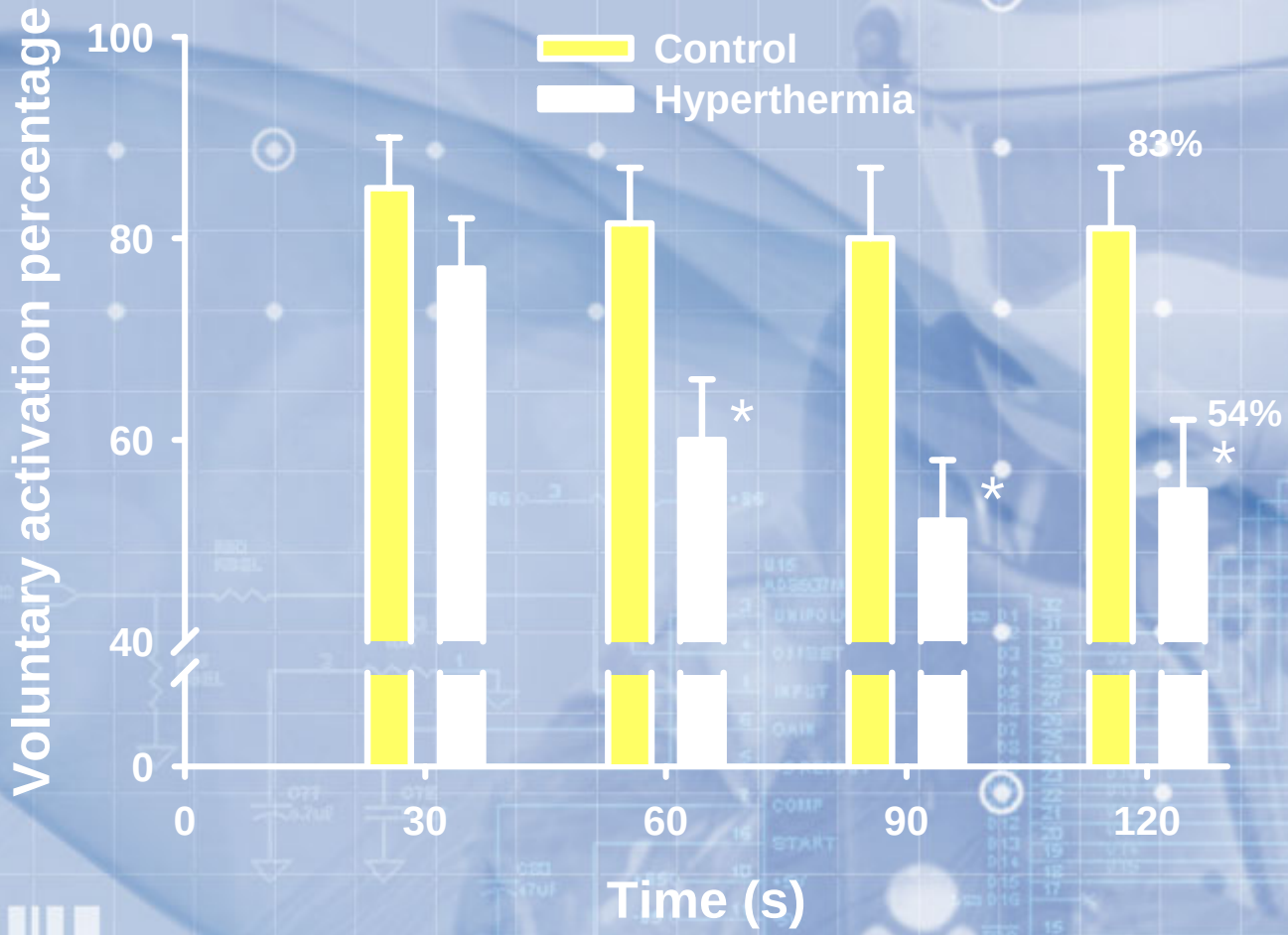
# Blood Distribution in the Heat




Rowell Human Circulation 1986

# Hyperthermia Reduces Voluntary Muscle Force Activation

Exercise to exhaustion (60%$VO_{2max}$) in hot or temperate; sustained MVC knee, voluntary activation by electrical stimulation to nervus femoris (Control $T_c$ = 38°C; Hyperthermia $T_c$ = 40°C)




* Significantly lower than control (P<0.05)

Nybo & Nielsen JAP 2001

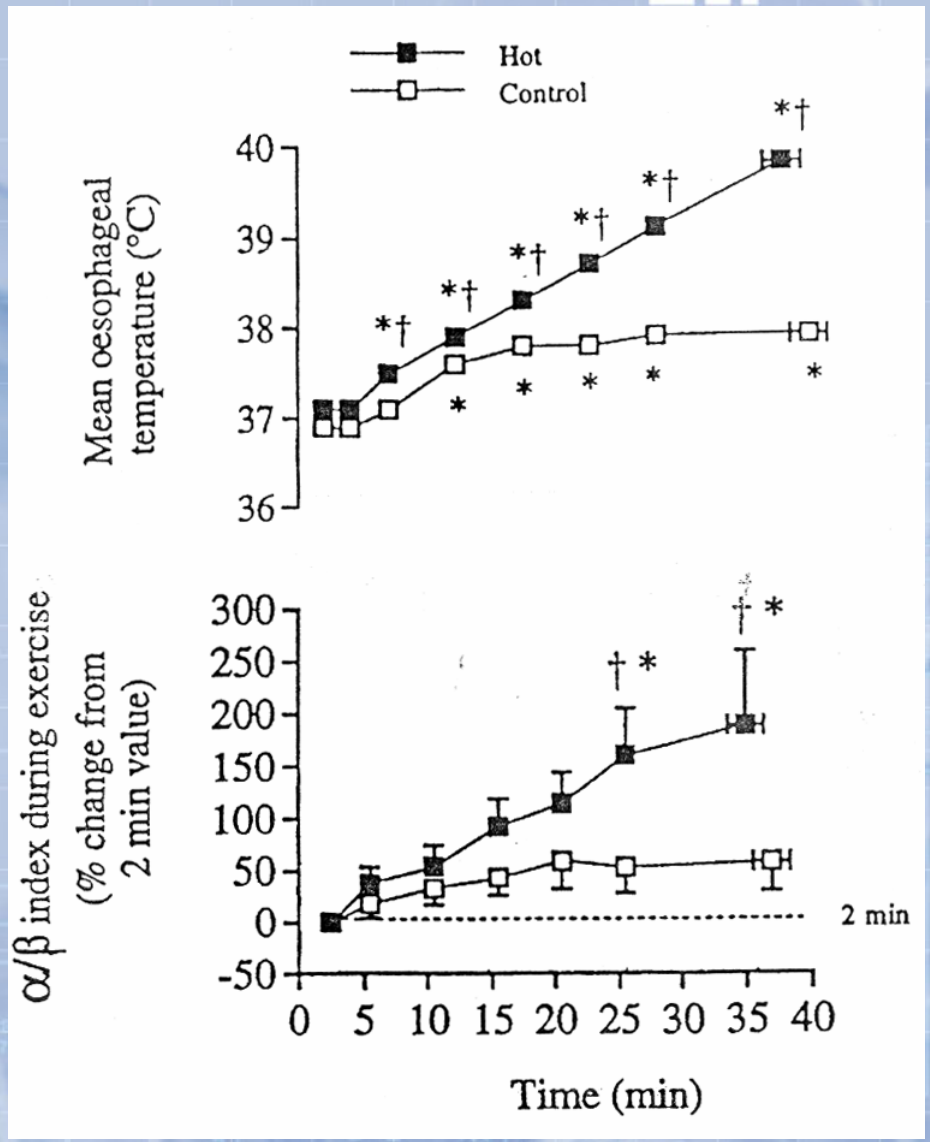
# Hyperthermia Reduces Brain EEG Activity

**Exercise (60% $VO_{2max}$) to Exhaustion in hot & temperate climates.**

**Frontal Brain EEG activity related to drowsiness (↑ α freq &↓ β freq).**

**Heat Stress induced lower β freq & α/β index was highly correlated with $T_{es}$ ($r^2 = 0.98$)**

Nielsen et al., Pflug. Arch. 2001

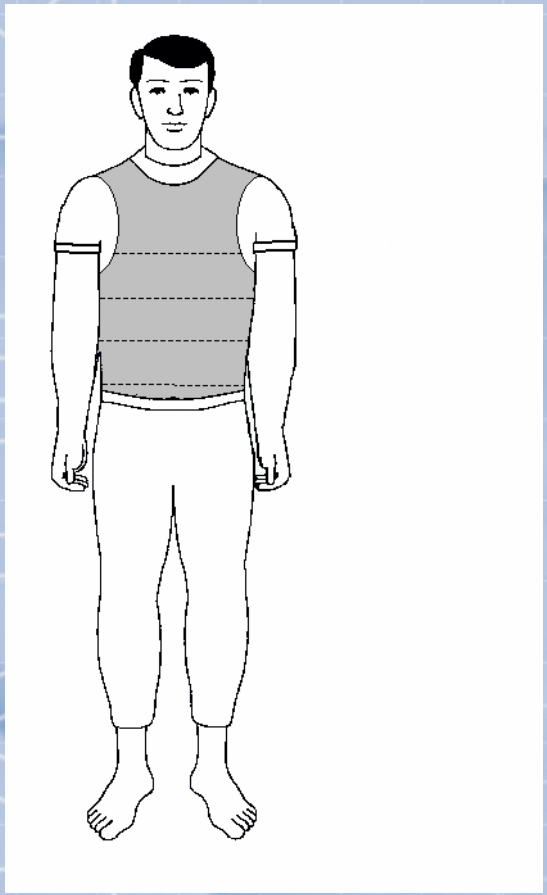


# Microclimate Cooling Benefits

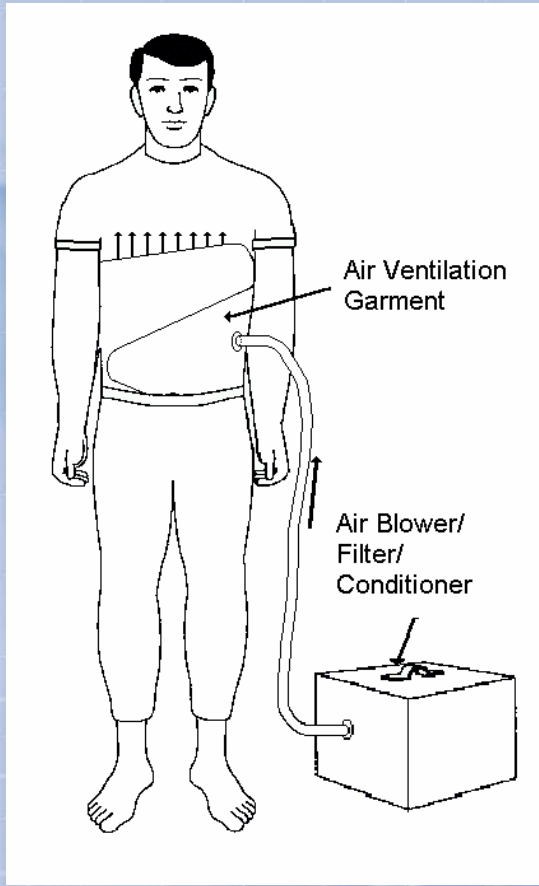
| | | |
|---|---|---|
| Reduction in core temperature | | Increased mission duration |
| Reduction in skin temperature | | Decrease in hydration needs |
| Reduction in heart rate | = | Improved mental acuity |
| Reduction in sweat rate | | Maintain physical performance |

***With cooling, the Soldier is STRONGER LONGER and MENTALLY SHARPER***

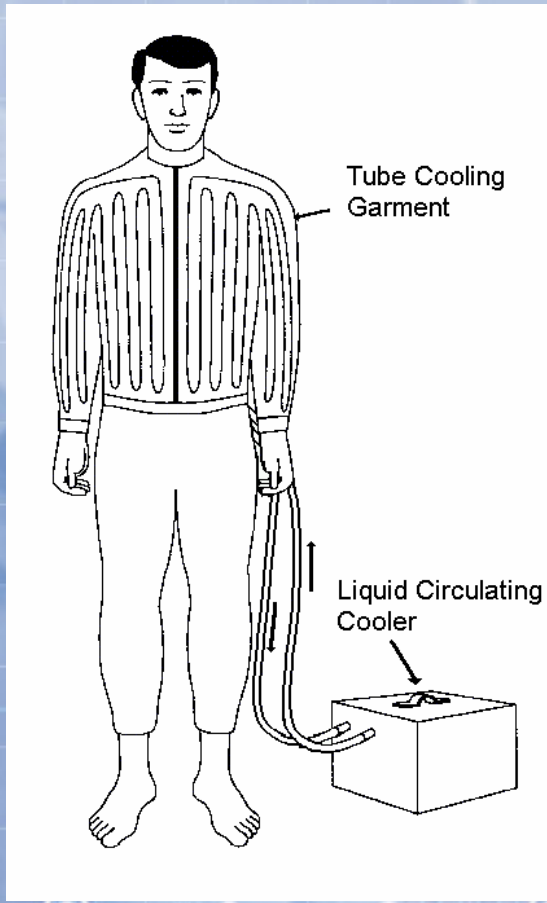
# Microclimate Cooling Concepts



Heat Storage Garment

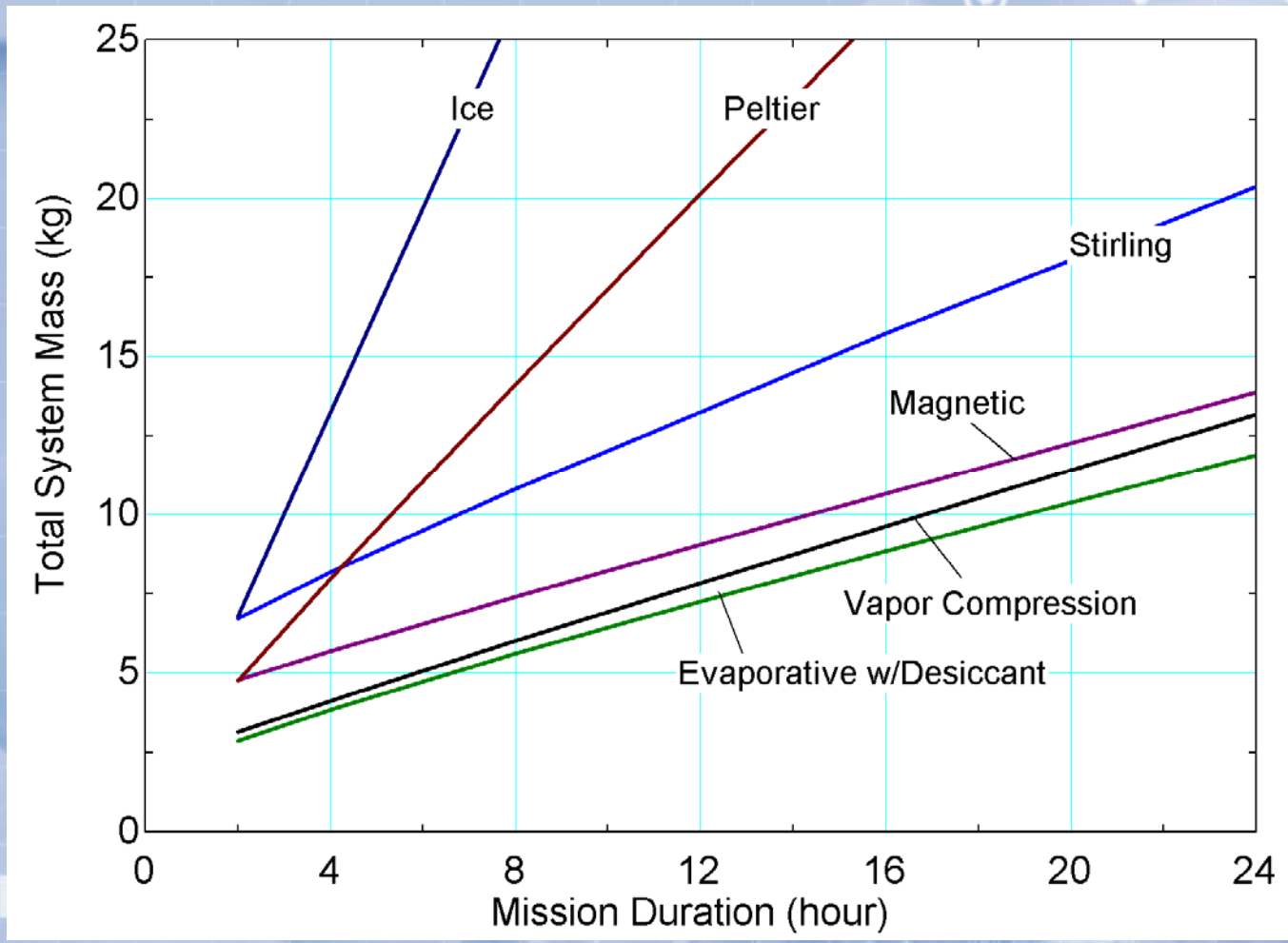



Air System




Liquid System

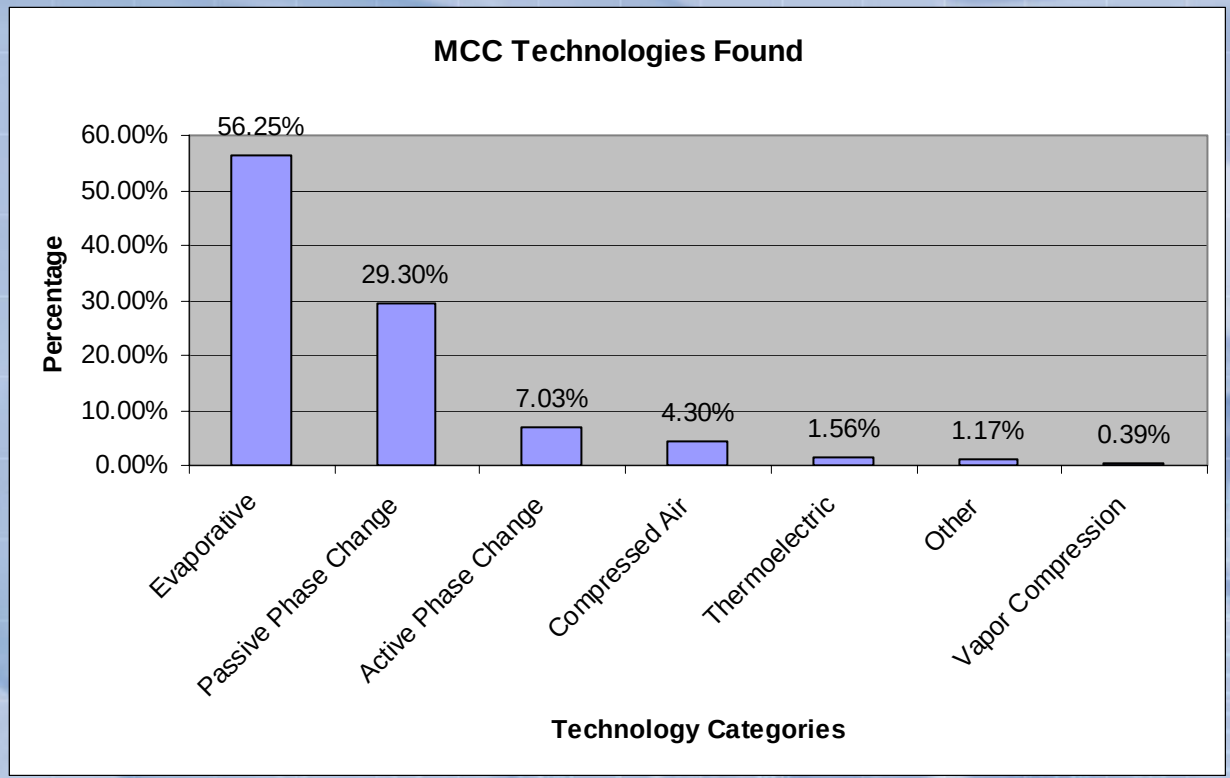
# Mass vs. Duration for Various Cooling Technologies



# Product Survey of Microclimate Cooling Systems

Identified over 250 products!

## Percentage of Products Per Technology



# Microclimate Cooling Systems
# Evaporative Systems

Evaporative Cooling Products: Items that absorb several times their weight in water when submerged

- •Relies on water evaporation to provide cooling
- •Multiple configurations (vest, hat, neck wrap) available
- •Outer clothing may have to be opened/removed to reactivate product
- •Nearly ineffective when worn under protective clothing
- •~$2-$260

**STATUS:** In production.

# Microclimate Cooling Systems
# Phase Change Systems

**DESCRIPTION:**

Vest carrier with four or six pockets into which frozen gel strips (starch – water mixture) are inserted to provide cooling.

**SPECIFICATIONS:**

- Used Navy shipboard since 1991
- ~12 pounds (six pocket version)
- ~8 pounds (four pocket version)
- Approximately 2 hours between gel strip exchange
- Approximately 200 watts of cooling (six pocket version)

**STATUS:** In production.

# Microclimate Cooling Systems
# Personal Ice Cooling System (PICS)

**DESCRIPTION:**
A battery powered mini pump circulates chilled water between the NBC sealed ice bag and a tube garment to remove metabolic heat from the body.


**SPECIFICATIONS:**
- 30 minute ice change-out
- 250 watts (estimated)
- Four hour battery change-out
- Three alkaline D-cell batteries
- Weight: 11 pounds

**STATUS:** In production.

# Microclimate Cooling Systems
# Commercial Ice-based Active System

Active Phase Change Material (Ice based/liquid circulating) Products: Chilled water pumped from an ice reservoir to a tube lined cooling garment

- •Requires freezer to recharge ice
- •Requires cooler to transport ice
- •Cooling rate decreases over time
- •Pass-through device may be required in outer clothing to accommodate tubing
- •Some systems are man mounted; others are hand carried and set down
- •Cooling rate/duration dependent on amount of PCM
- •~$350-$1900

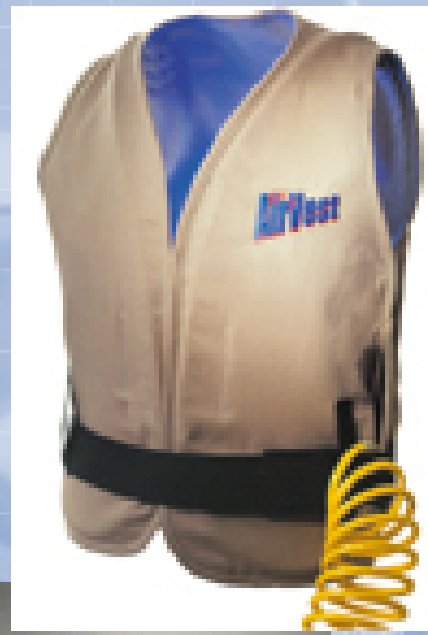
**STATUS:** In production.

# Microclimate Cooling Systems
# Compressed Air Systems

Compressed Air Products: Air distribution garment connected to a compressed air source

- •User is tethered; system is not autonomous
- •Pass-through device may be required in outer clothing to accommodate hose
- •Compressed air source required
- •Cooling rate constant over time
- •Some products use vortex tubes to refrigerate air
- •~$100-$260

**STATUS:** In production.



# Microclimate Cooling Systems
# Thermoelectric (Peltier) Systems

Thermoelectric (Peltier) Products: Refrigeration unit chills and circulates a fluid to a tube type cooling garment

- DC current applied across two dissimilar materials, resulting in a temperature differential
- Low efficiency (i.e. requires more batteries )
- Pass-through device may be required in outer clothing to accommodate tubing
- Cooling rate constant over time
- Few moving parts
- ~$50-$714

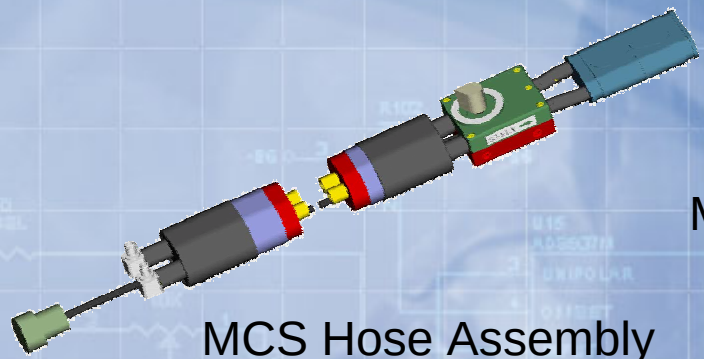
**STATUS:** Development required.

Note: DARPA is developing a prototype based on advanced materials. Several years away.

# Microclimate Cooling Systems
# Air Warrior System

- Liquid circulated to garment to cool aircrew
- Autonomous cooler takes heat from the fluid rejects heat to warm (ambient) air
- Current Applications:
  - OH-58D
  - UH-60A/L
  - CH-47D
  - M9 ACE

Microclimate Cooling Unit (MCU)



MCS Hose Assembly

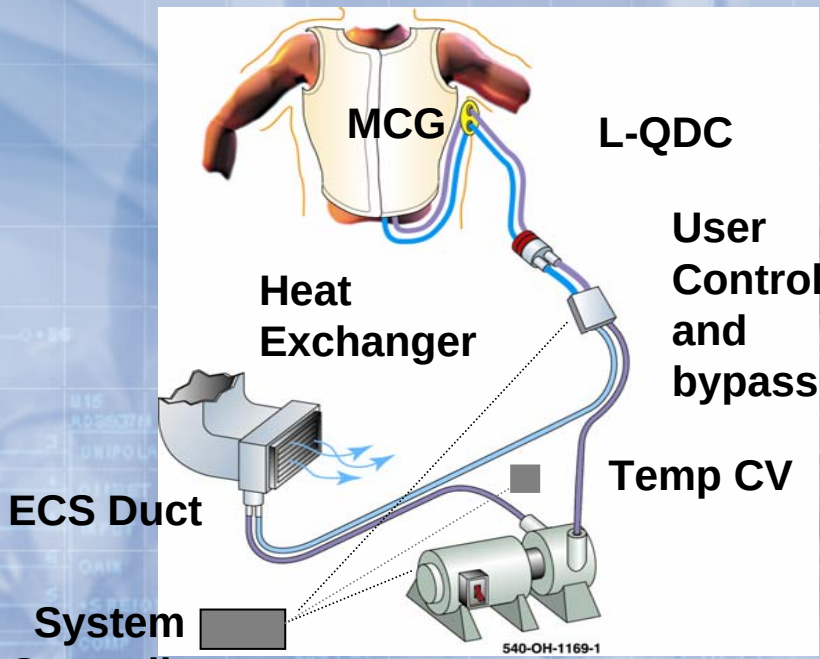
Microclimate Cooling Garment (MCG)

**STATUS:** In production.

# Microclimate Cooling Systems
# AH-64 (Apache) Cooling System

- Heat Exchanger incorporated inside cool air ducts - chills coolant directly
- MCG and coolant umbilical identical to baseline MCS

**STATUS:** In production.



# Microclimate Cooling Systems Cool The Force Add-on for HMMWVs

-13000 HMMWVs receiving Add-on-Armor kits including Air Conditioner (Red Dot)
- Foster Miller, Inc. liquid circulating system down-selected
- Provides cooling for 1-4 occupants

**STATUS:** Limited operational evaluation (Iraq) in progress.

**Heat Exchanger**

**Flow Control Assembly**

# Microclimate Cooling Systems
# Compact Vapor Compression System

**ASPEN SPECIFICATIONS:**

- 120 watts of cooling (95 F ambient)
- Power: 50 watts @ 24 Vdc
- Weight: 4.65 lbs
- Size: 175 $in^3$

**FMI SPECIFICATIONS:**

- 110 watts of cooling (95 F ambient)
- Power: 50 watts @ 24 Vdc
- Weight: 4.0 lbs
- Size: 170 $in^3$

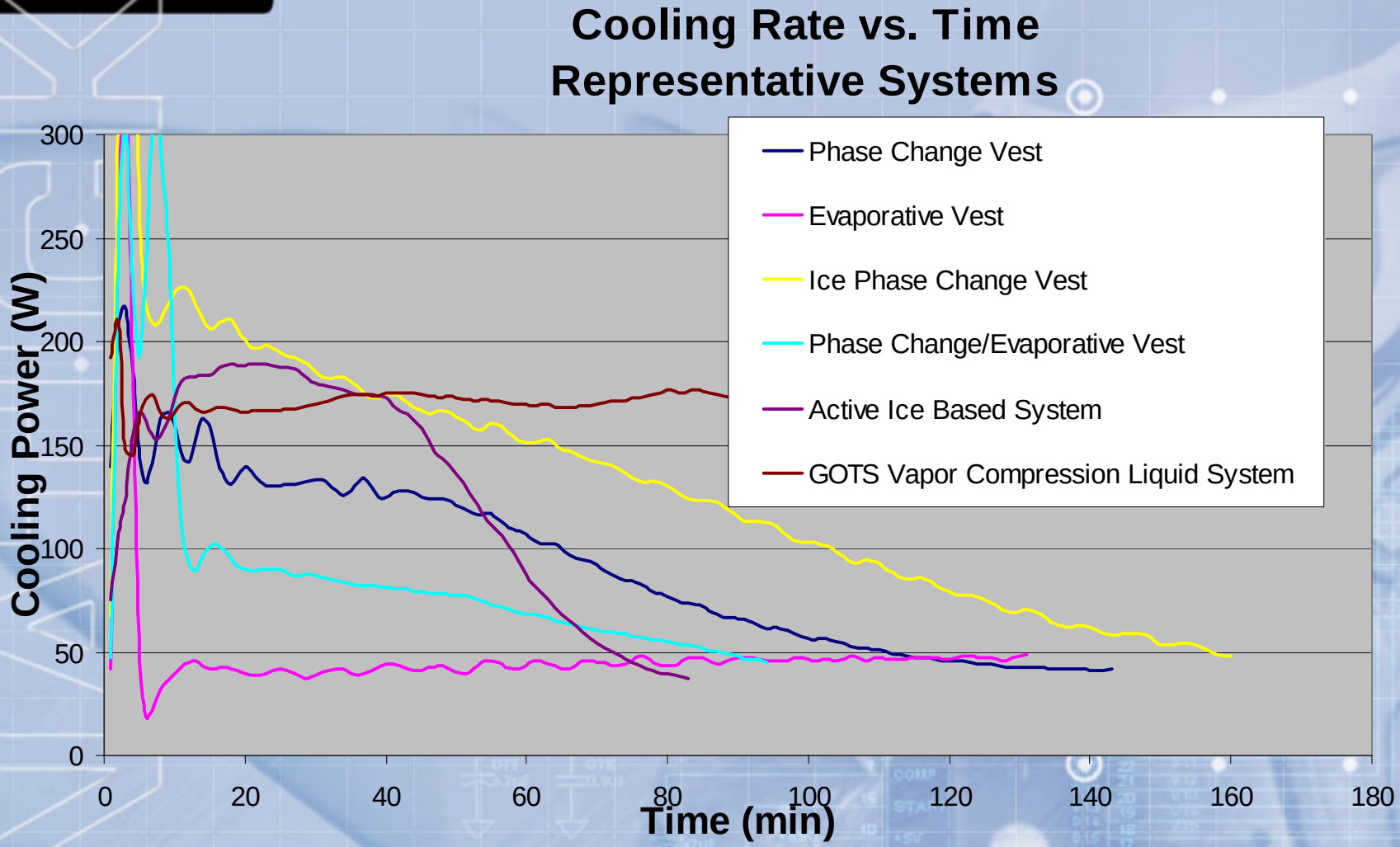
**STATUS:** TRL5 prototype. Estimated 6 months development for production.

# Microclimate Cooling Systems
# Future Vapor Compression System

- Liquid circulating vapor compression cooling system
- 120 watts of cooling @ 95°F
- ≤6 pounds including power source
- Cooling fluid delivered at 77°F
- ≤92 $in^3$ (1.5 liters)

**STATUS:** Prototype anticipated in May 2006. Smaller (33%) version 1 to 2 years away.

# Microclimate Cooling Systems
# Evaluation of Various Existing Systems



# Microclimate Cooling Systems General Observations

- 250± commercial Microclimate Cooling products available
- Evaporative systems are the most common type, followed by Passive PCM
- Evaporative systems provide minimal cooling under protective clothing
- Ice based Passive systems provide more cooling than paraffin systems on a per weight basis
- All have technical, logistical, cost, and operational trade-offs
- Cannot identify the “best” product without understanding specific user needs/requirements
- Vapor compression systems hold the most promise for near term dismounted Warfighter needs.

# Microclimate Cooling User Response

**Subject:** RE: Air Warrior

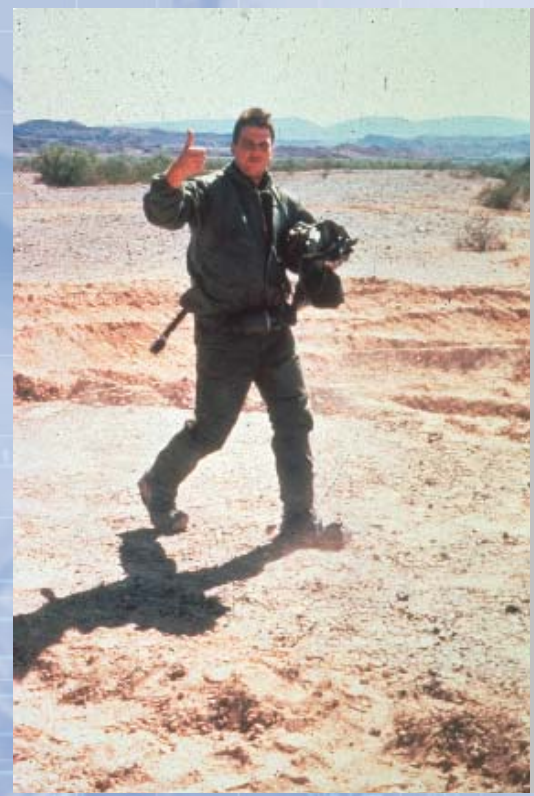
"***The crew agreed this system is the best thing we've done for the helicopter since we put a rotor on it!!! The system greatly enhances the crew's comfort level and significantly reduces fatigue.***"

LTC PAUL AMBROSE
LSA ANACONDA, IRAQ
Used with permission.

# Microclimate Cooling

Without microclimate cooling, he's not just hot, he's a heat stress casualty

Without cooling



With cooling