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How Body Pressure Distribution Can Map Soldier Comfort

Michael Megiveron
U.S. Army Tank Automotive Research Development Engineering Center (TARDEC)

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
21 MAR 2011	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
How Body Pressure Distribution Can Map Soldier Comfort	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Michael Megiveron	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA	**21632**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA	**TACOM/TARDEC/RDECOM**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
Presented at SAE 2011 World Congress April 12-14, 2011 Detroit, Michigan, USA, The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

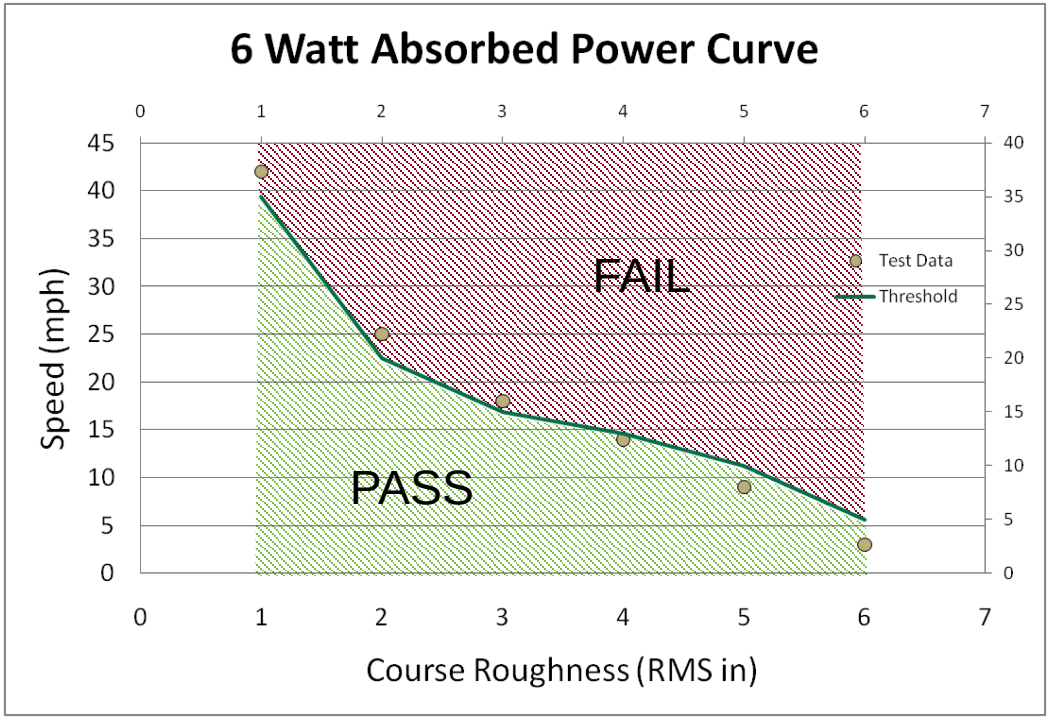
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**15**	

Agenda

- Background
  - Comfort Metrics
    - Absorbed Power
    - Pressure Change Rate Root-mean-square (Pcrms)
    - Area Pressure Change Rate (aPcrms)
    - Seat Pressure Distribution (SPD%)
- Military Environment
  - What makes it unique?
- Case Studies
  - Mine Resistant Ambush Protected (MRAP) Seat Enhancement
  - High Mobility Multipurpose Wheeled Vehicle (HMMWV) Seat Upgrade
- Conclusion

Comfort Metrics (Acceleration Based)

- Absorbed Power
  - Human tolerance threshold ~6 Watts
  - Army's primary ride quality metric
  - $AP = \sum_{i=0}^{N} K_i A_i{}^2 \, rms$
    - K_i ≡ Conversion constant, function of the frequency i
    - A_i rms ≡ Root mean square of the acceleration



Comfort Metrics (Pressure Based)

- Seat Pressure Distribution (SPD%)
  - Seat's ability to uniformly distribute pressure.
  - $$SPD\% = \frac{\sum_{i=1}^{n}(p_i - p_m)^2}{4np_m^2}$$
    - n ≡ total number of nonzero cell elements
    - p_i ≡ pressure at the i^{th} cell
    - p_m ≡ mean pressure of the n elements
  - Lower values describe more uniform pressure distribution.
- Pressure Change Rate Root-Mean-Square (Pcrms)
  - Ability of the seat to absorb sudden changes in vibration
  - $$Pcrms = \left\{\frac{1}{T}\int_0^T \left(\frac{dP(t)}{dt}\right)^2 dt\right\}^{1/2}$$
    - T ≡ time period
    - P(t) ≡ dynamic pressure history
  - A lower value shows a more comfortable seat

Military Environment

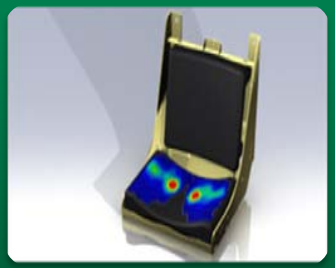
- Gear Worn
  - Affects seating position and posture.
  - Makes measurements on seat back difficult.

- Road Roughness
  - Automotive: 0.058–0.193 g's RMS
  - Military: 0.069–0.362 g's RMS
    - Harder to test, rougher on occupant
- Operational Environment
  - Exit quickly and ready to fight.
  - Alert to threats while on the move.

Case Studies

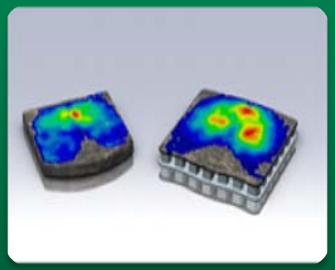
Test Location

- U.S. Army TARDEC, Warren MI
- Ride Motion Simulator (RMS)



MRAP Troop Seat Enhancement

- Developed, tested, and fielded comfort enhancement



HMMWV Seat Cushion Upgrade

- Analyze proposed cushion against baseline cushion

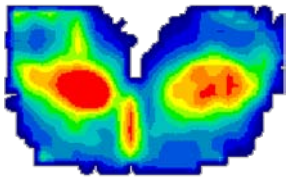
MRAP Troop Seat Enhancement

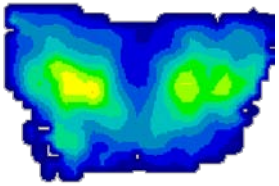
- Objective
  - Improve comfort with an add-on piece.
    - 2 enhancement designed and tested

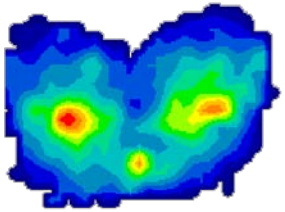
Baseline

Enhancement 1

Enhancement 2

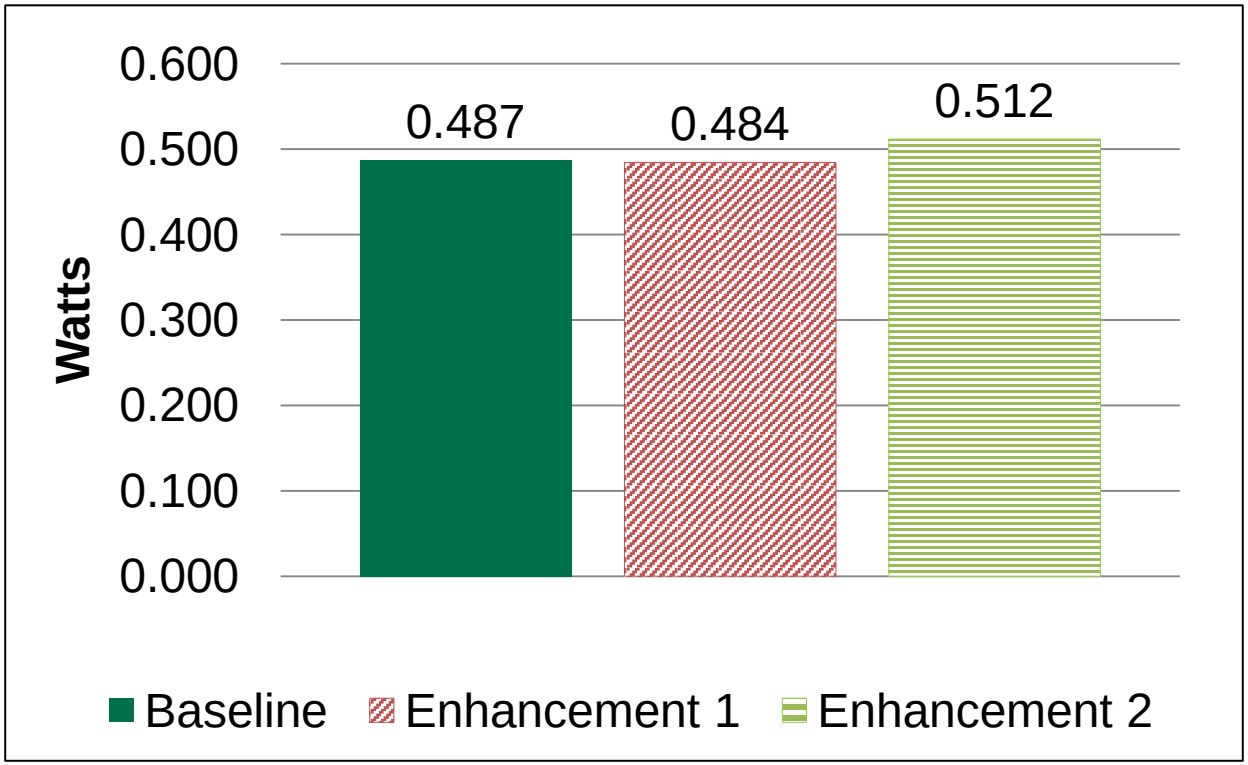






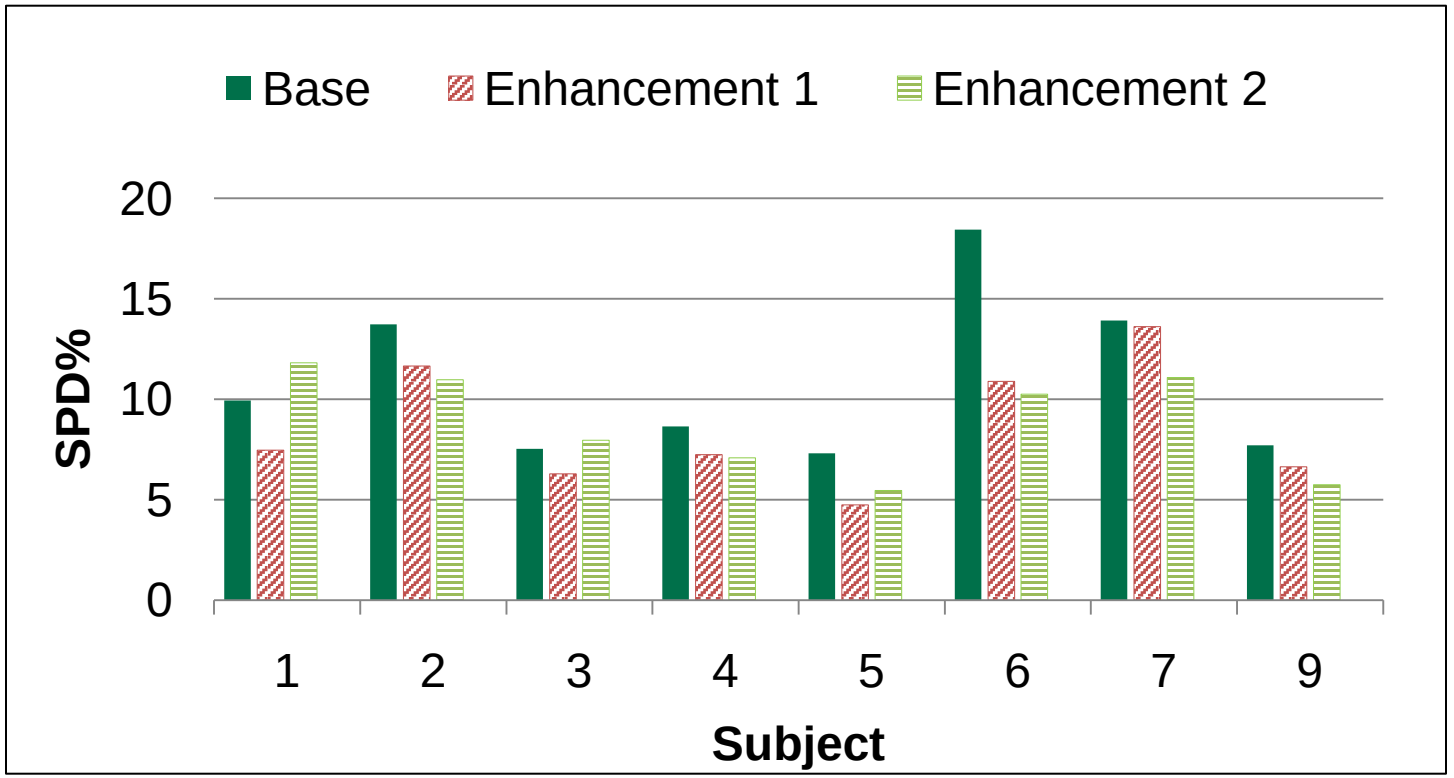
MRAP Troop Seat Enhancement

- Absorbed Power
  - Ineffective measure
  - Vibration at ischial tuberosity too similar on different seats



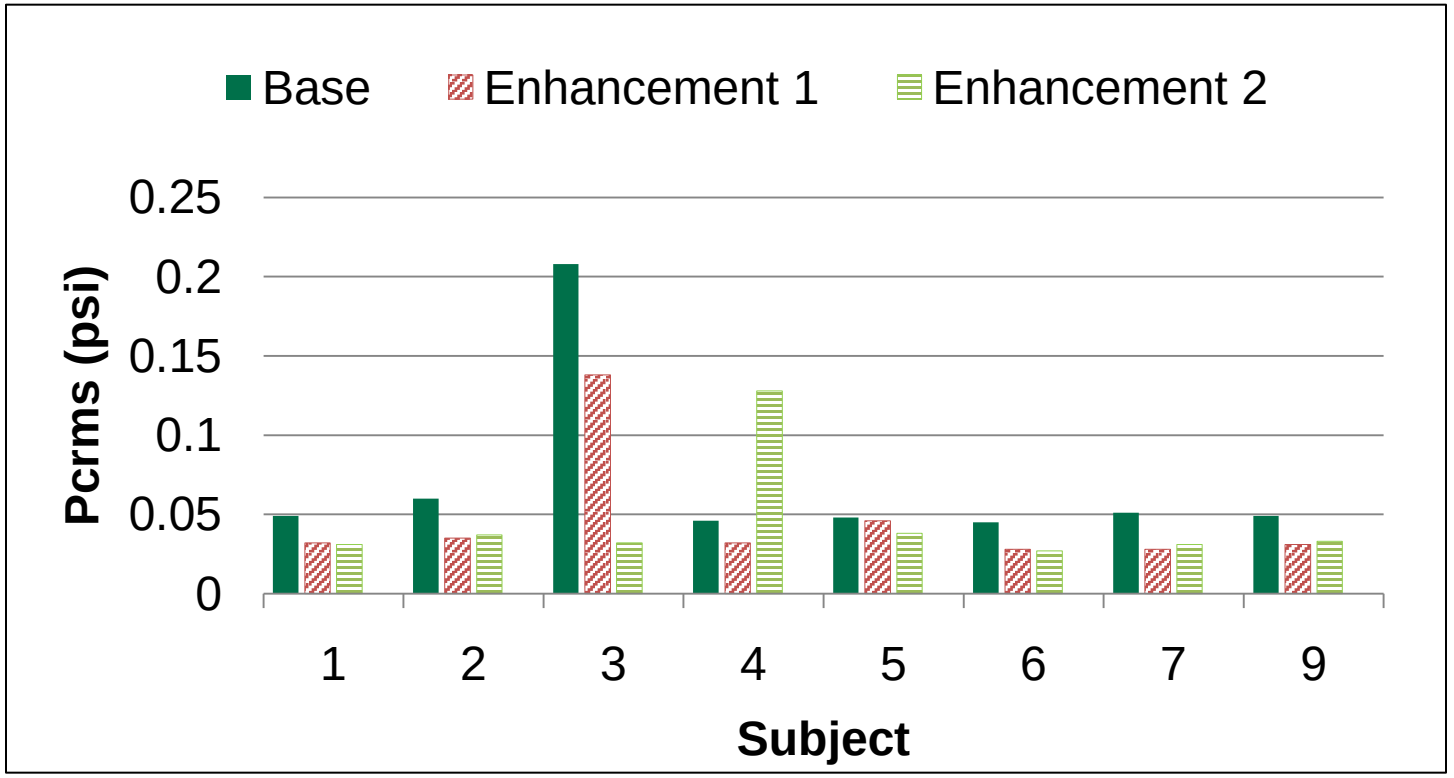
MRAP Troop Seat Enhancement

- Seat Pressure Distribution (SPD%)
  - Inconsistent but enhancements show improvement



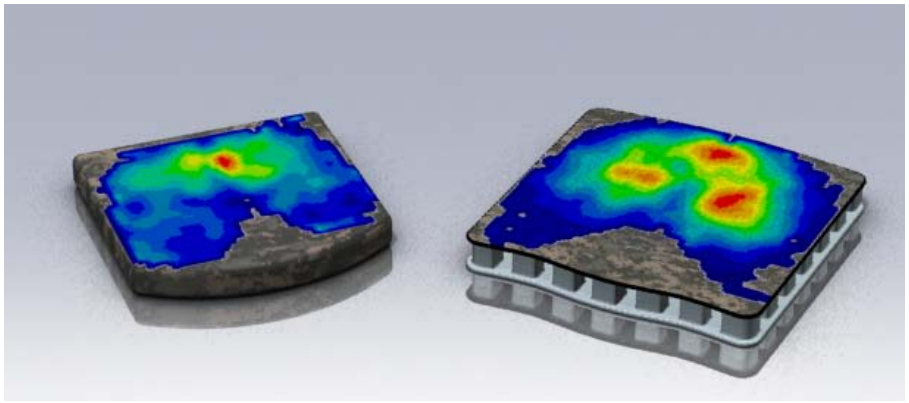
MRAP Troop Seat Enhancement

- Pressure Change Rate Root Mean Square (Pcrms)
  - Inconsistent but enhancements show improvement
  - Small deviation



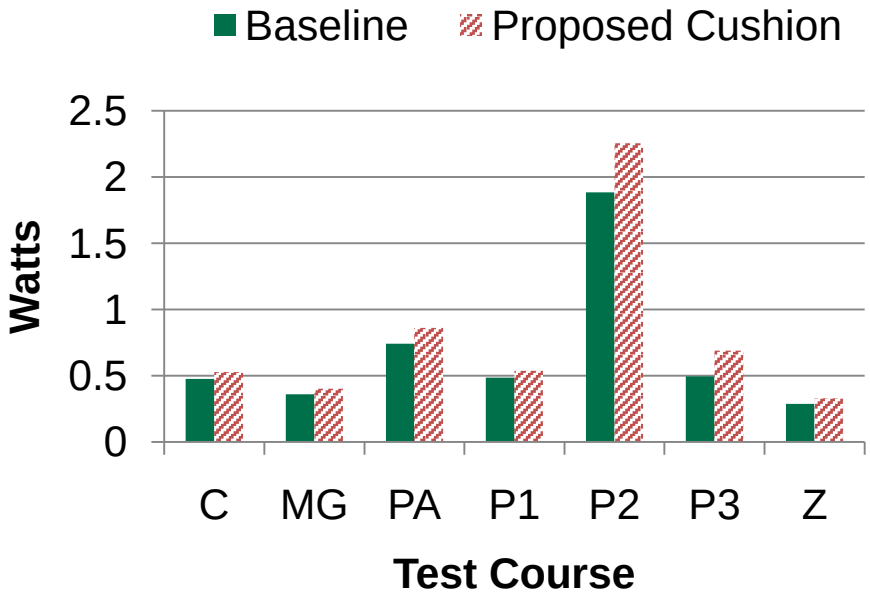
HMMWV Seat Cushion Upgrade

- Objective
  - Analyze proposed cushion against baseline cushion
- Seat Cushions
  - Baseline: typical automotive open cell foam
  - Proposed: soft plastic shock absorbing structure



HMMWV Seat Cushion Upgrade

- Absorbed Power
  - Baseline Preformed better than proposed cushion



C - Churchville

MG - Munson Gravel

PA - Perryman A

P1 - Perryman 1

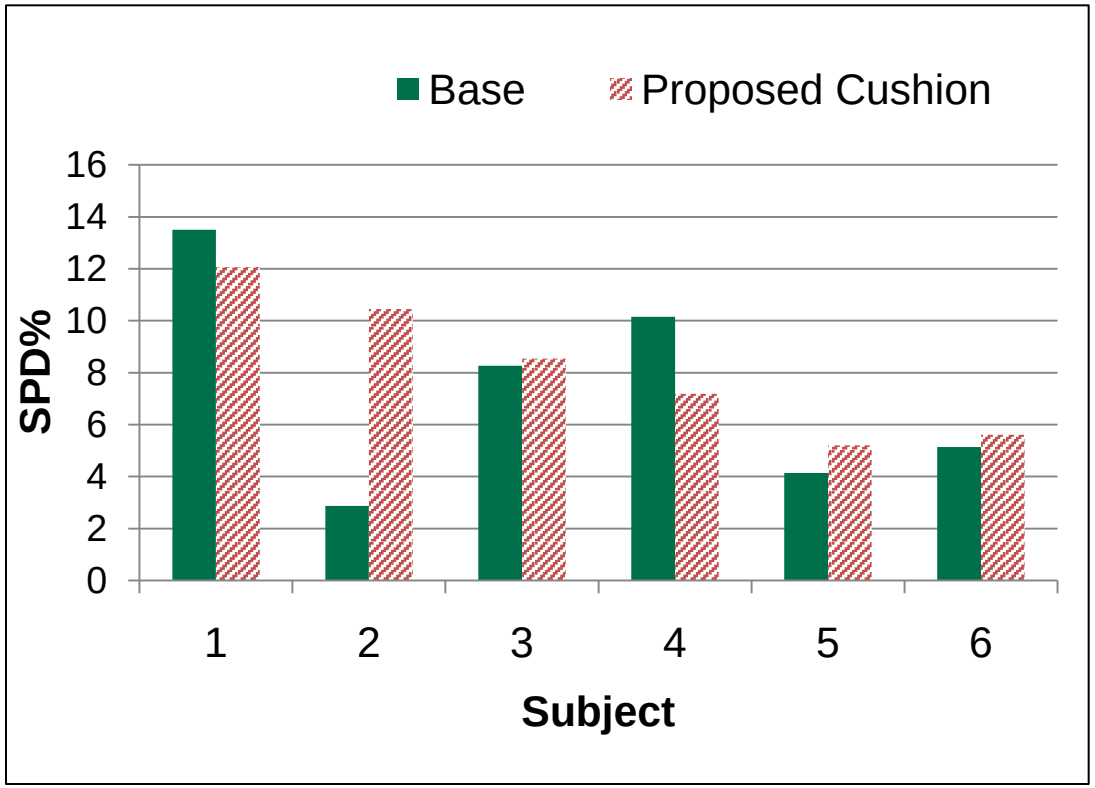
P2 - Perryman 2

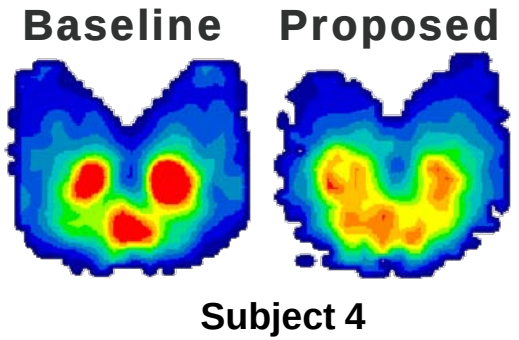
P3 - Perryman 3

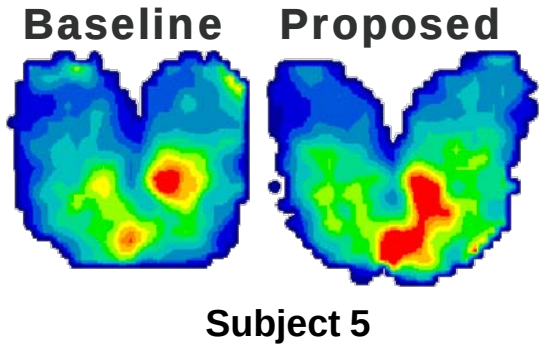
Z - Z-direction white noise

HMMWV Seat Cushion Upgrade

- Seat Pressure Distribution (SPD%)
  - Inconsistent which seat was better

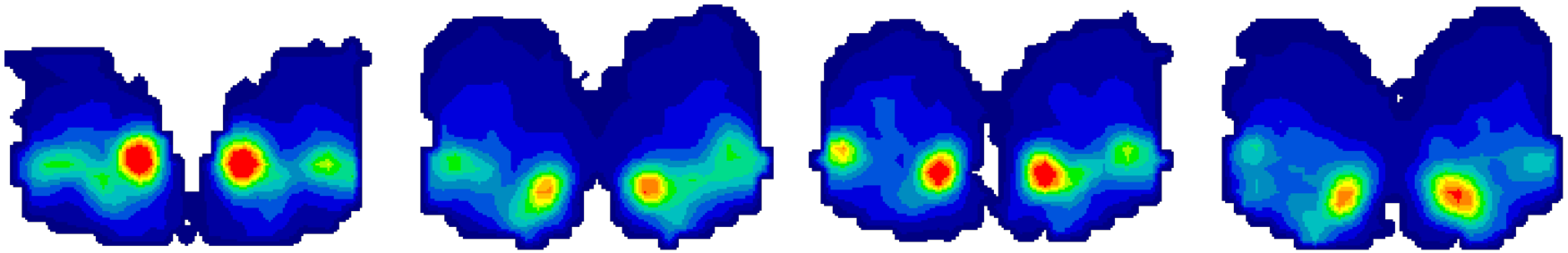






Case Study Outcomes

- MRAP Crew Seat Enhancement
  - Enhancement designs were combined
  - Final design fielded to theater



Baseline | Enhancement 1 | Enhancement 2 | Hybrid Design

- HMMWV Seat Cushion Upgrade
  - No significant comfort increase with proposed cushion
  - Proposed cushion not integrated

Conclusion

- BPD shown to help describe a military seat's comfort
  - Compliments but doesn't replace absorbed power.
- Metrics can only compare seats subject dependent.
- Difficult to measure interaction of subject, body armor and seat back.
- Best test method needs to be determined.
- Until process can be refined, questionnaires and other subjective data is still needed in seat evaluations.