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# Whole-body Vibration related Ergonomic Study of U.S. Railroad Locomotives & Operators



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# Aim of study:

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- Ergonomic factors in relation to whole-body vibration exposure in US locomotives
- Assess Cab and Seats currently in use
- Assess ergonomic factors and confounders possibly mitigating WBV exposure effects



# Background:

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- Low back disorder occupational risk factors
  - Bending, twisting, lifting,
  - **awkward posture & WBV**
- Rail bound vehicles:
  - Unique environment with exposure to multi-axis whole-body vibration and shocks (WBV):
    - lateral acceleration
    - frequent irregular shocks
    - events often unpredictable

# Epidemiology of neck and lower back disorders :

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- Method:

- self-administered 200-item survey (cross-section)
  - Musculoskeletal diseases (back, neck, large joints)
  - Working conditions and ergonomic factors
  - Psycho-social stress (Karasak et al Model)
- US & Canada randomly selected group of active railroad engineers and a comparison group (civil engineers)
- Response rate: 47% for railroad engineers (n=1195) and 41% for controls (n=323).

# Epidemiology of neck and lower back disorders :

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- Serious LBP and neck/shoulder complaints among locomotive engineers was ~ double c/w control group
- Adjusted\* OR for sciatic pain (a back condition with neurological complications) was 2.17 (95% CI 1.33-3.56) \*Age, gender, race, smoking, non-occupational WBV exposure
- Attenuation of risk after controlling for psychosocial work factors, time sitting at work, and time at work being bothered by vibration



# Method:

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- Standardized cross-sectional questionnaire survey of North-American locomotive engineers (n= 1195) and controls (n=323).
- Comparison with a non-exposed control group (sedentary office worker)
- 50+ locomotive cab and seat inspections
- Observation of tasks and body movements of locomotive operators during routine revenue service

# Results: Seat transfer function

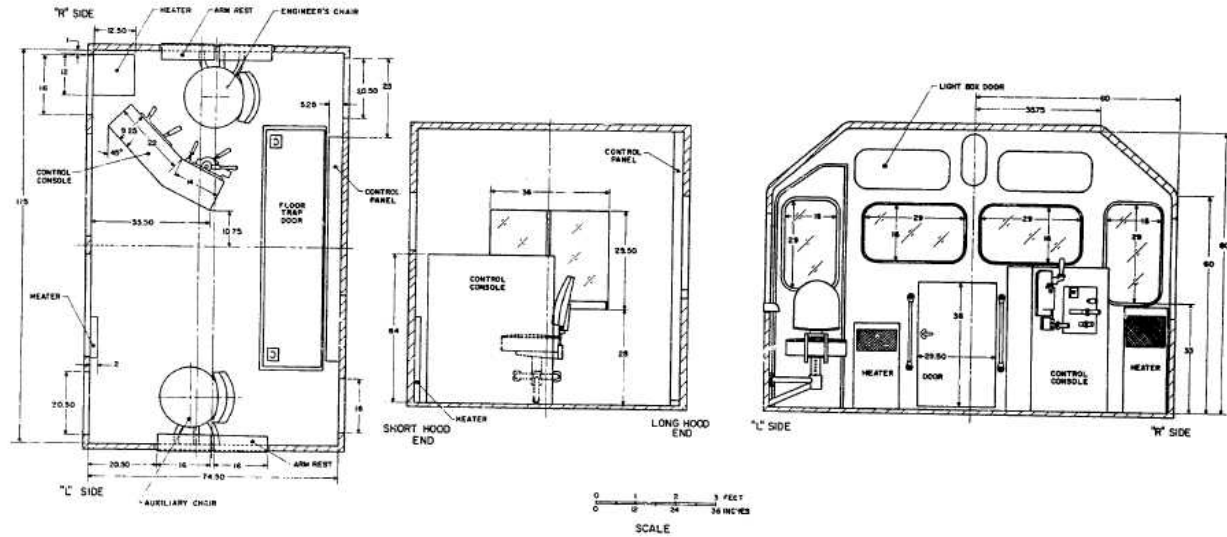
(SEAT)

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n	42	42	42
	x	y	z
<b><u>Mean</u></b>	<b><u>1.43</u></b>	<b><u>1.21</u></b>	<b><u>0.97</u></b>
<b>Min</b>	<b>1.00</b>	<b>1.03</b>	<b>0.61</b>
<b>Max</b>	<b>2.32</b>	<b>1.51</b>	<b>1.56</b>
<b>SD</b>	<b>0.32</b>	<b>0.11</b>	<b>0.17</b>
<b>Mode</b>	<b>1.20</b>	<b>1.25</b>	<b>0.92</b>

# Traditional cab and seat design ("AAR Control Stand")

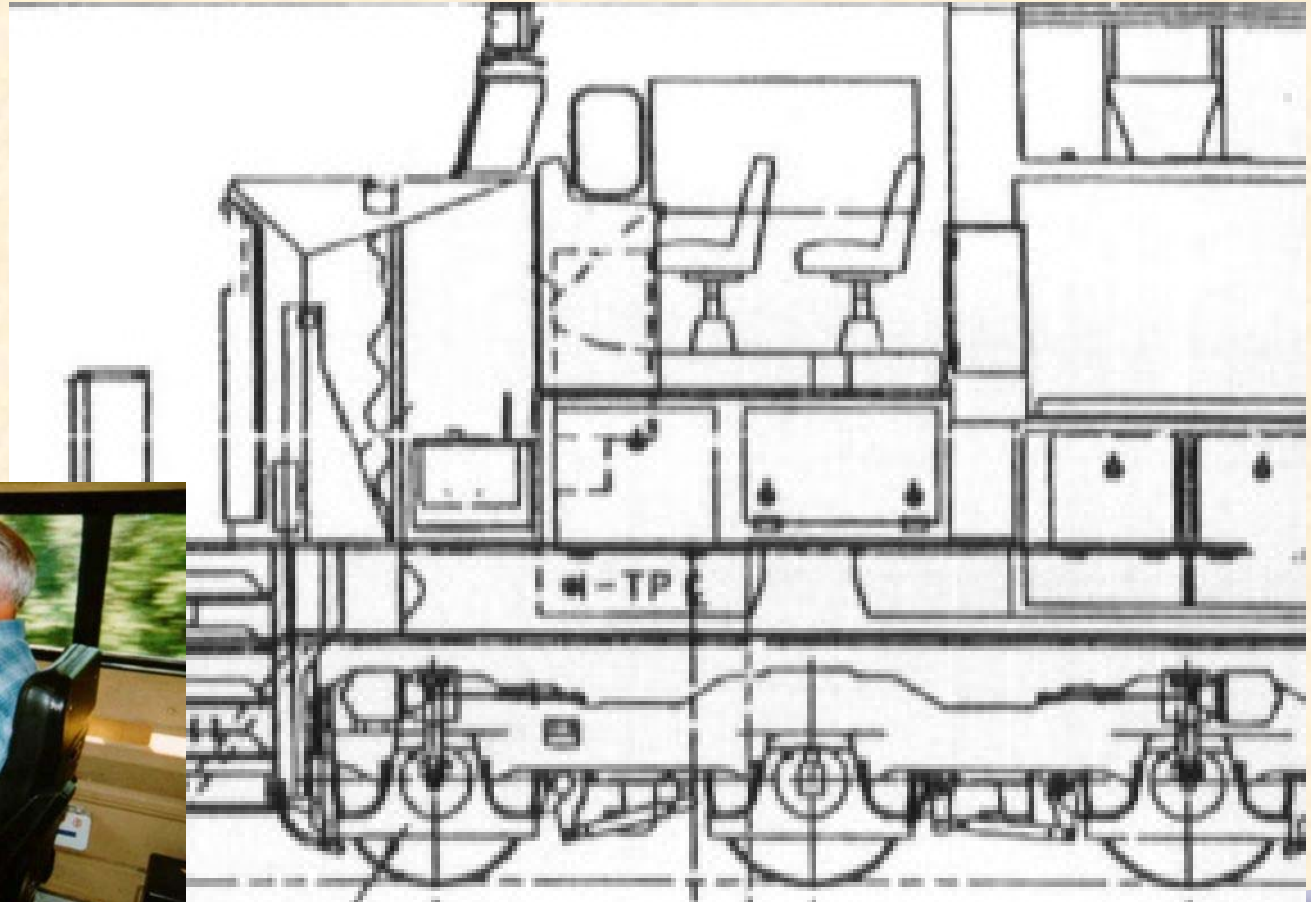
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# New Generation "Wide body" locomotive cab and seating

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# Yard switcher GP40-2 (2004) AAR control stand

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Communication radio

reverser

Throttle



# Field observations:

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# Posture during yard - switching



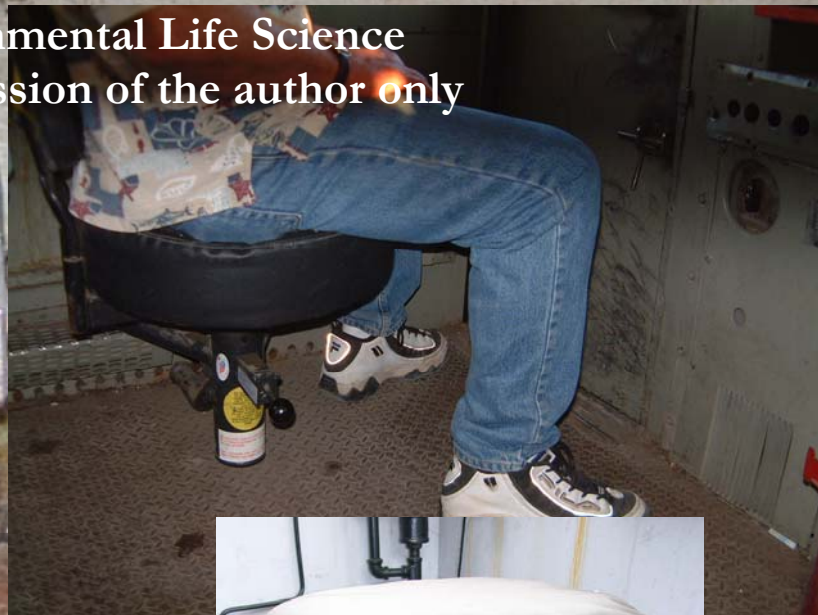


# Conductor and fireman seat SD40-2 cab

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# Traditional toad stool



# Newer type floor and side mounted seat

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# Model GE C41-8, 4135 hp, built in 1991 (UP 9077) – USSC Seat retrofitted (2001)

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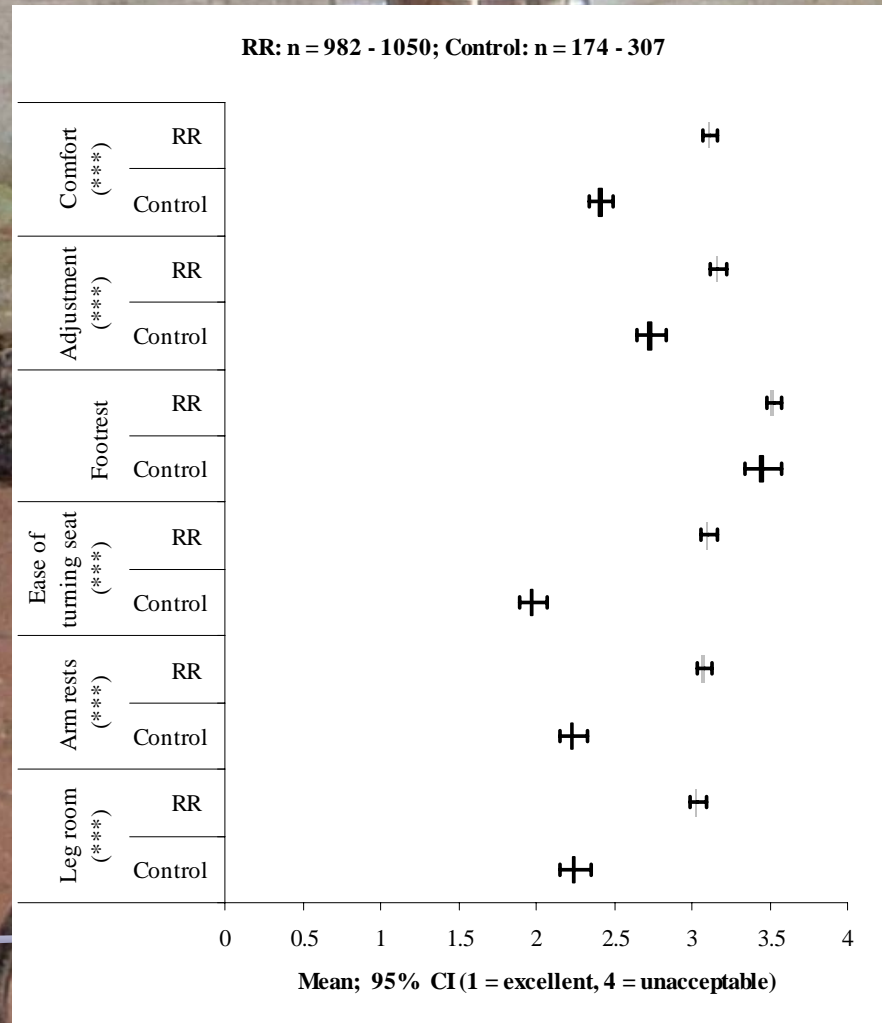
# Seat characteristics (n=1419)

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	Locomotive operator		Control		$\chi^2$	p( $\chi^2$ )
	(%)	N	(%)	N		
<b>Arm rest</b>	<b>82.3</b>	<b>1011</b>	<b>89.1</b>	<b>313</b>	<b>8.29</b>	<b>0.004</b>
<b>Any back support</b>	<b>78.7</b>	<b>1043</b>	<b>90.3</b>	<b>310</b>	<b>21.24</b>	<b>&lt;0.001</b>
<b>Adjustable back support</b>	<b>30.5</b>	<b>1026</b>	<b>14.7</b>	<b>299</b>	<b>29.33</b>	<b>&lt;0.001</b>
<b>Air cushion system</b>	<b>11.1</b>	<b>1026</b>	<b>37.4</b>	<b>297</b>	<b>112.55</b>	<b>&lt;0.001</b>
<b>Round seat pad (toad stool)</b>	<b>20.0</b>	<b>985</b>	<b>23.1</b>	<b>303</b>	<b>1.36</b>	<b>0.244</b>
<b>Footrest available?</b>	<b>34.1</b>	<b>954</b>	<b>5.6</b>	<b>305</b>	<b>94.83</b>	<b>&lt;0.001</b>



# Evaluation of seat features and comfort rating (\*\*\*) $p < 0.001$





# Wide-body locomotives working conditions and rating (n=1019)

	YES	
	(%)	N
<i>Any particular problem with wide body locomotives?</i>	<b>62.7</b>	<b>1019</b>
<b>Cab lay out</b>	<b>49.1</b>	<b>639</b>
<b>Vibration</b>	<b>21.9</b>	<b>639</b>
<b>Air conditioning</b>	<b>11.1</b>	<b>639</b>
<b>Ventilation</b>	<b>6.4</b>	<b>639</b>

# Important vibration risk

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## assessment factors:

- ☞ Vibration basic values
- ☞ Crest factor, MTVV, VDV etc.
- ☞ Resonance range (hertz) (PSD)?
- ☞ Exposure duration
- ☞ Seating Posture
- ☞ Adequate rest periods
- ☞ Consider all facts in overall analysis



# Other discussion points

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- ✦ Locomotive engineers are working often overtime and long hours (+60 h/week)
- ✦ Seats in use are often defective, loose and poorly adjustable
- ✦ Seat position and mounting contributes to ergonomic postural stress (back).
- ✦ A health survey indicates high MSD risk

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# Discussion

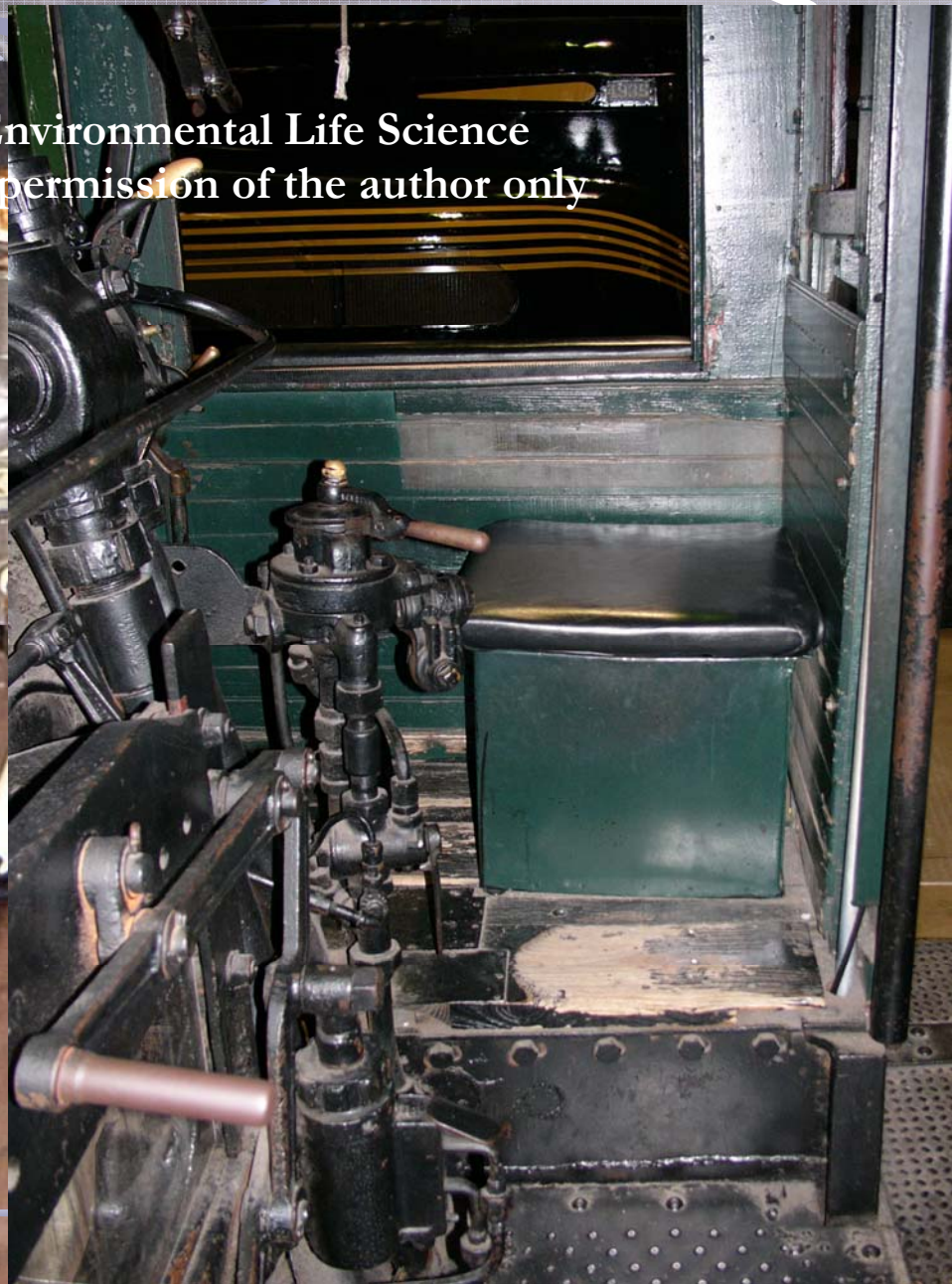
## Study limitation:

- No exact time motion / postural measurements over work shift
- CUELA measuring system
- Logistical problems
- Equipment variation
- Participation



# Steam engine seat...

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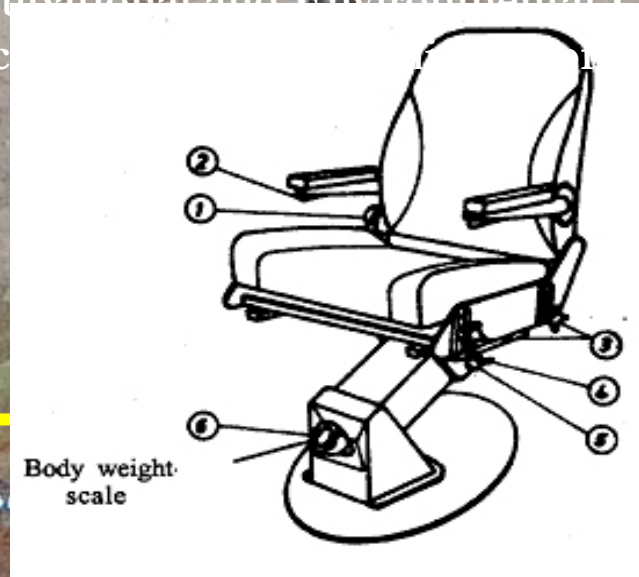
## "Union" Inductive Train Communication-Cab Signals



# SHOCK & VIBRATION - History

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July 1969



German Railroads developed an “idealized” dampened locomotive cab seat.

Fig.5.1 Proposed standard seat for The German Federal Railways

1. Backrest incline adjustment
2. Seat cushion adjustment (angle & height)
3. Seat cushion adjustment
4. Seat depth adjustment
5. Fixed turn position
6. Body weight adjustment



# SHOCK & VIBRATION History

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1969

Swiss standard locomotive seat.

Primary criteria was to dampen vertical vibration.



Fig. 5.2 Standard seat of the Swiss Federal Railways installed in the cab



# Standard locomotive seat (FRG) since 1970/80





# Suspension seat with head support - passenger locomotive - FRG 2002

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FRA-OPP-73-1

PB 213 225

**HUMAN FACTORS SURVEY  
OF LOCOMOTIVE CABS**



30 JUNE 1972

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Springfield VA 22151

PREPARED FOR  
DEPARTMENT OF TRANSPORTATION  
FEDERAL RAILROAD ADMINISTRATION  
Washington, D.C.


- 1. Improve seats – eliminate the “toad stool.”**
- 2. Measure locomotive cab vibrations.**
- 3. Dampen vibration.**
- 4. Design appropriate foot rest. Piece of pipe – not adequate.**

# The FEDERAL GOVERNMENT Studied Shock & Vibration in Locomotives in Order to Protect Real Employees

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PB 213 225


## HUMAN FACTORS SURVEY OF LOCOMOTIVE CABS



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Springfield VA 22151


PREPARED FOR  
**DEPARTMENT OF TRANSPORTATION**  
FEDERAL RAILROAD ADMINISTRATION  
Washington, D.C.



### Human Factors Guidelines for Locomotive Cabs

Office of Research  
and Development  
Washington, D.C. 20590

U.S. Department of Transportation  
John A. Volpe National Transportation Systems Center  
55 Broadway  
Cambridge MA 02142-1093



#### Locomotive Cab Human Factors Program

DOT/FRA/ORD-98/03  
DOT-VNTSC-FRA-98-8

Final Report  
November 1998

This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161

always expect a train

1972

1998



# Railroad Industry Concern:

## PASSENGERS FREIGHT EQUIPMENT

### ENVIRONMENTAL ANALYSIS- YARD HANDLING OF TOFC TRAFFIC



ASSOCIATION  
OF AMERICAN  
RAILROADS

### Measurement and Analysis of Lengthwise Rail Shock



Study Conducted by

ASSOCIATION OF AMERICAN RAILROADS  
Operations and Maintenance Department  
Damage Prevention and Loading Services  
50 F Street, N.W.  
Washington, D.C. 20001  
(Printed in U.S.A.)

July 1995

Report DP 3-95

UNDERSTANDING SHOCK AND VIBRATION was developed at the direction of AAR member railroads to explain what shock and vibration are, how these forces are measured, and the effects they can have on freight.

The video is divided into two segments. Segment one examines how engineers measure shock and vibration. Segment two introduces ways in which this information can be collected, and sophisticated methods of interpreting the data.



Association of American Railroads  
Damage Prevention and Loading Services  
50 F Street, N.W., Washington, DC 20001  
(202) 639-2340

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Association of American Railroads

Understanding SHOCK and VIBRATION



Understanding  
SHOCK  
and  
VIBRATION

### Study of the Shock & Vibration Environment in Boxcars



Study Conducted by

ASSOCIATION OF AMERICAN RAILROADS  
Operations and Maintenance Department  
DAMAGE PREVENTION AND FREIGHT CLAIM SECTION  
50 F Street, N.W.  
Washington, DC 20001

November 1992

Report: DP 7-92

### Study of the Railroad Shock and Vibration Environment for Roadrailer Equipment



Conducted by

ASSOCIATION OF AMERICAN RAILROADS  
Operations and Maintenance Department  
DAMAGE PREVENTION AND FREIGHT CLAIM SERVICE  
50 F Street, N.W.  
Washington, DC 20001

January 1992

Report No. DP 1-92

### Analysis of Yard Handling Shocks on Multi-Level Rail Cars

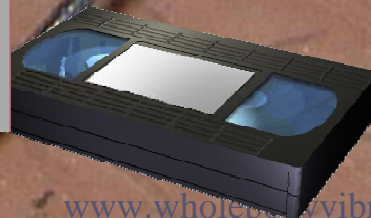


Study Conducted by

ASSOCIATION OF AMERICAN RAILROADS  
Operations and Maintenance Department  
DAMAGE PREVENTION AND FREIGHT CLAIM SECTION  
50 F Street, N.W.  
Washington, DC 20001

September 1993

Report: DP 4-93



www.wholebodyvibr

# Summary and Conclusion

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- Seated locomotive engineers are exposed to unique vibration and shock in all three directions.
- Lateral vibration and unpredictable irregular shocks are of concern.
- Current seats, including newer type seats appear inadequate to reduce vibration and provide sufficient postural support.
- Combined ergonomic risk factors and WBV exposure
- Preventive engineering and interventions utilizing current technology and medical knowledge appear prudent



Thank you for your attention.

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# Texas Railroad Research Yard 2004



Figure 5: EUDD demonstrator in the Virtual Reality Laboratory

# European Union Driver Desk Concept (EUDD) 2004