Shock Mitigating Seat Single Impact Test Program

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DRDC Atlantic

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Canada

Introduction

Speeds in excess of 40 kts

Introduction

USN survey of self-reported injuries among special boat operators (2000):

- 154 special boat unit operators
- 121 reported injury events in mean service time of ~ 5 yrs.
- 34% lower back problems, 21% knee, 14% shoulder

In 722 person years of SBU exposure:

- 145 days hospitalization
- 2.5 yrs sick leave
- 11.5 yrs limited duty
- 5.6 times greater injury rate than navy average

Introduction

- Single impact tests
- Multiple jockey-style suspension seats
- Naval Engineering Test Establishment (NETE)
- Defence Research and Development Canada (DRDC)
- Goal to reduce risk of acute and chronic injury to personnel serving on board high speed craft (HSC)

DRDC | RDDC

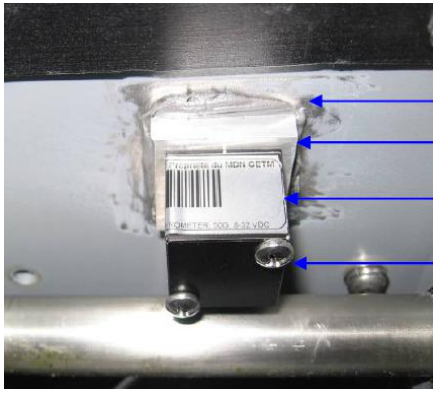
Excellent
Engineering
Solutions

WEHR

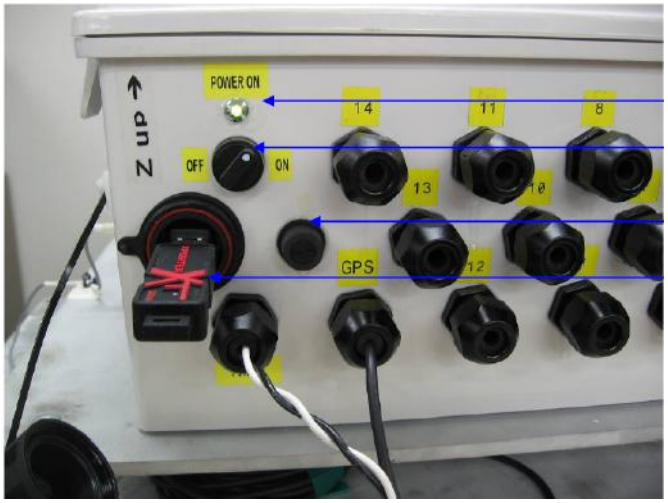
Introduction

- Loads
  - Measurements on board HSC
- Testing
  - Repeatable laboratory test procedure
- Evaluation
  - Various injury criteria

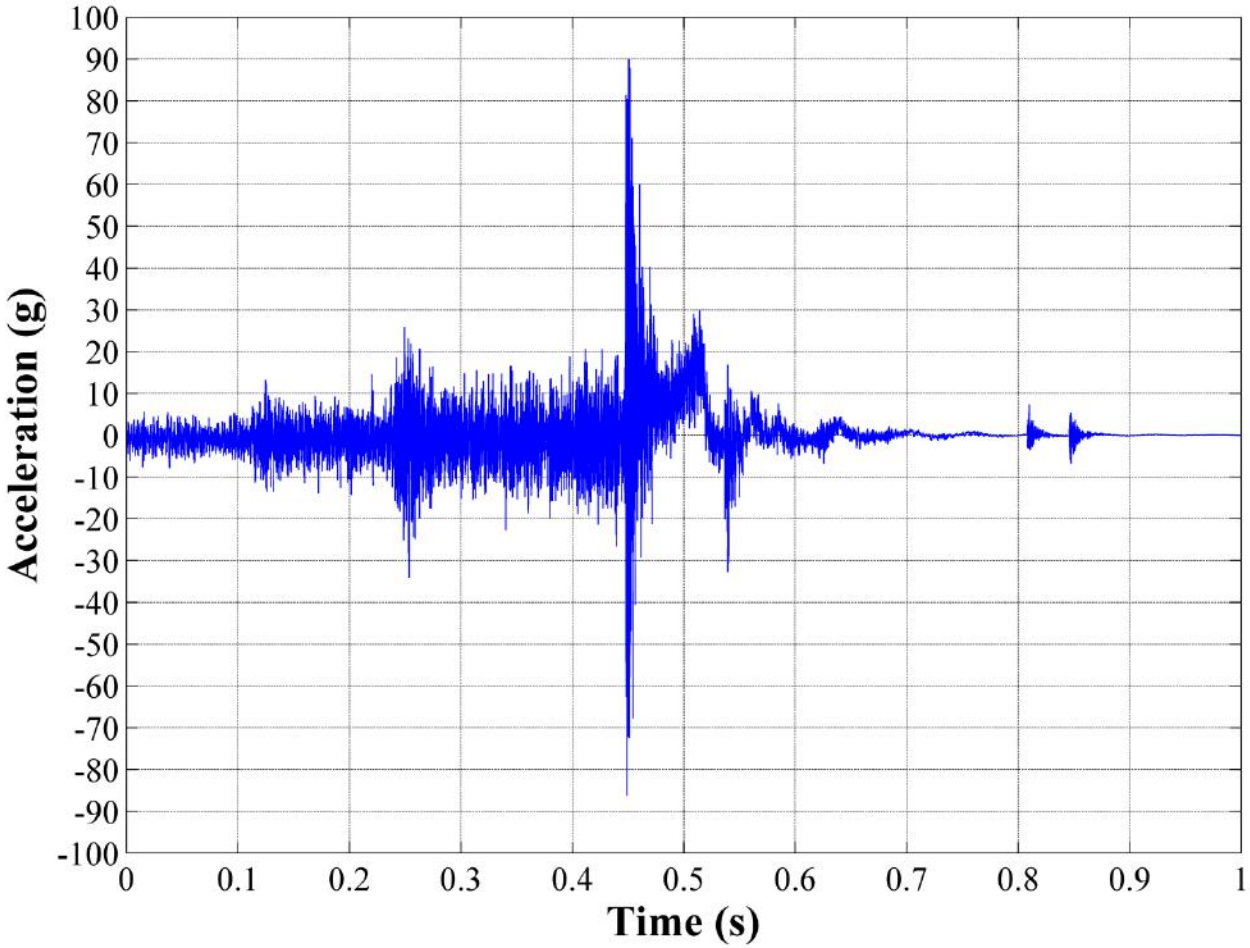
Loads



- Measured on ~30 ft RHIB
- DRDC - 2007, 2008
  - Wave buoy nearby
- Naval Engineering Test Establishment – ongoing
  - Semi-permanent DAS
  - Comprehensive suite of instrumentation
  - Wave data more difficult to acquire

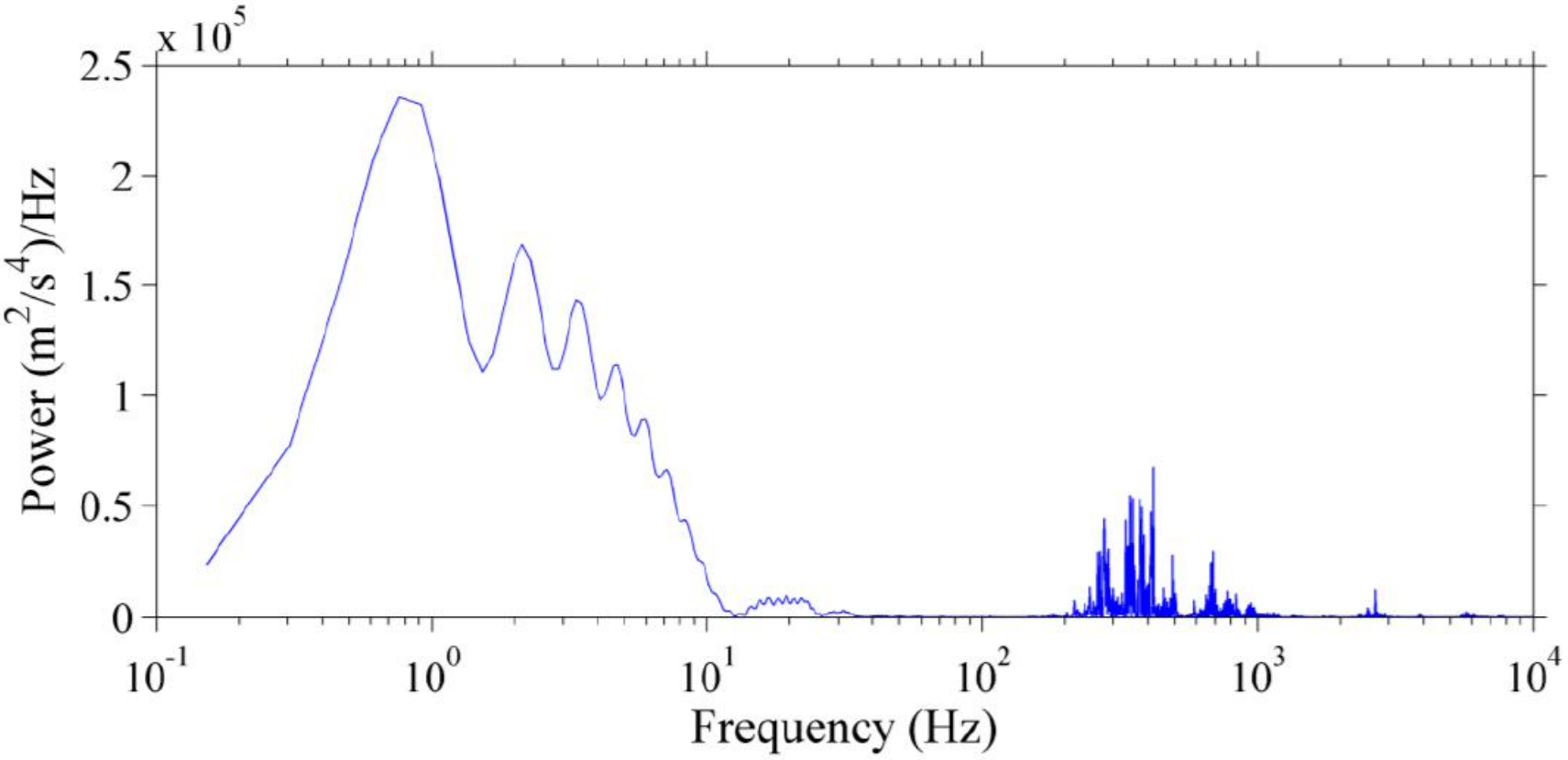


Loads


Acceleration (g)
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time (s)

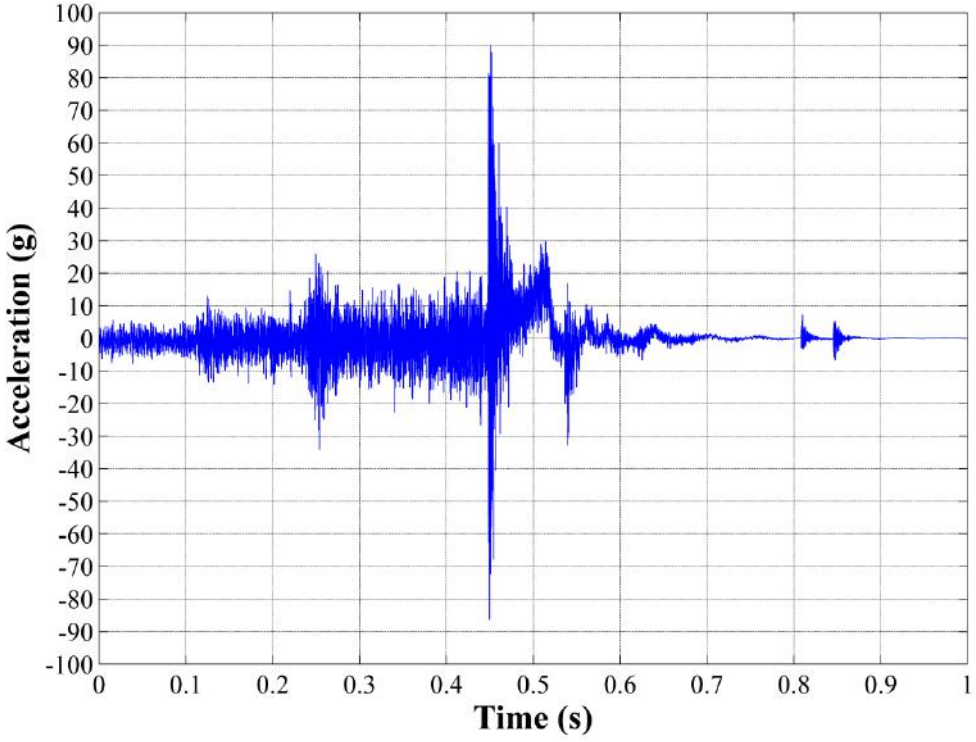
Loads

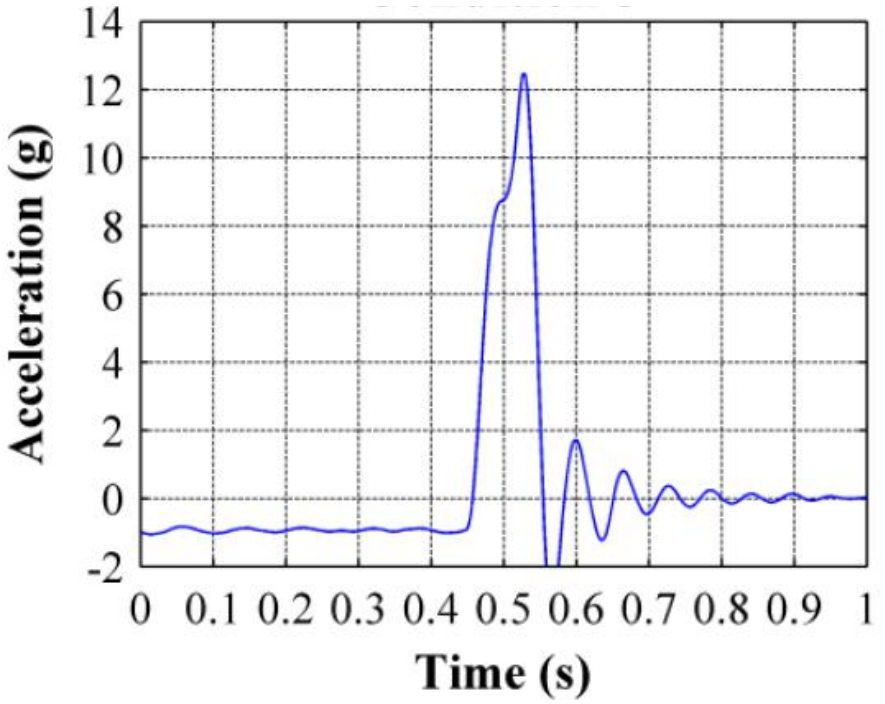
- Power spectrum



Loads

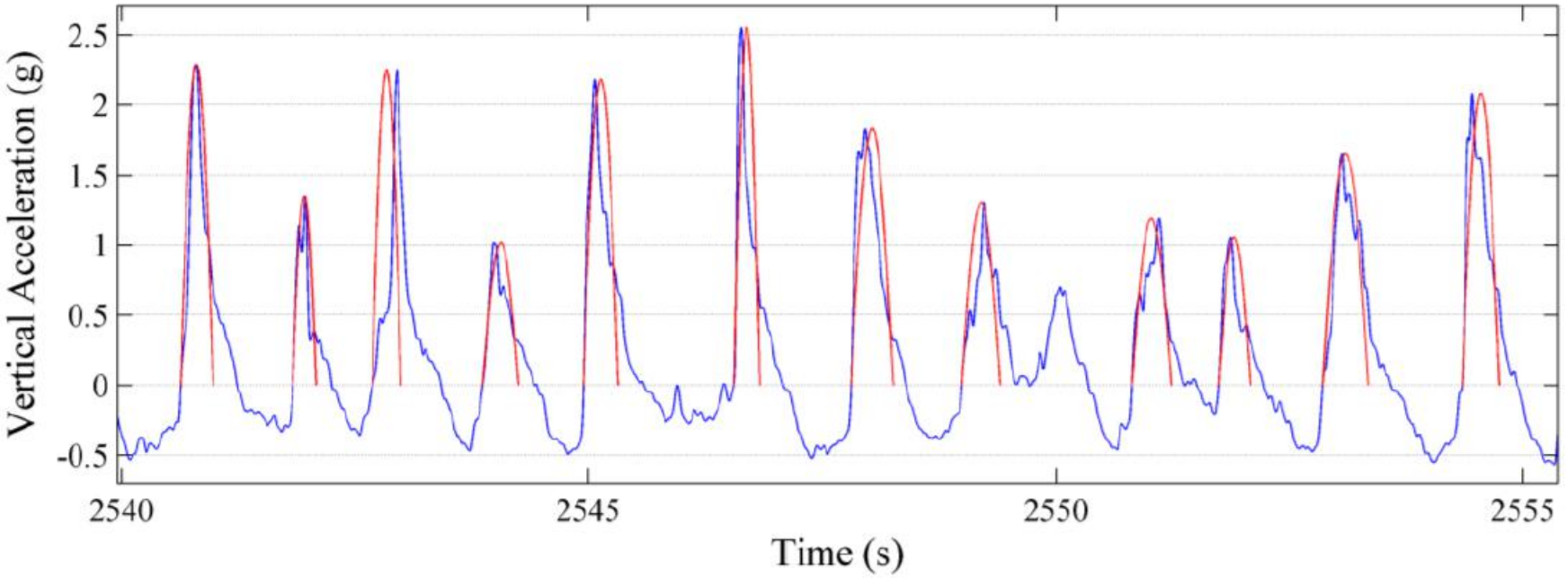
- 30 Hz low-pass filter





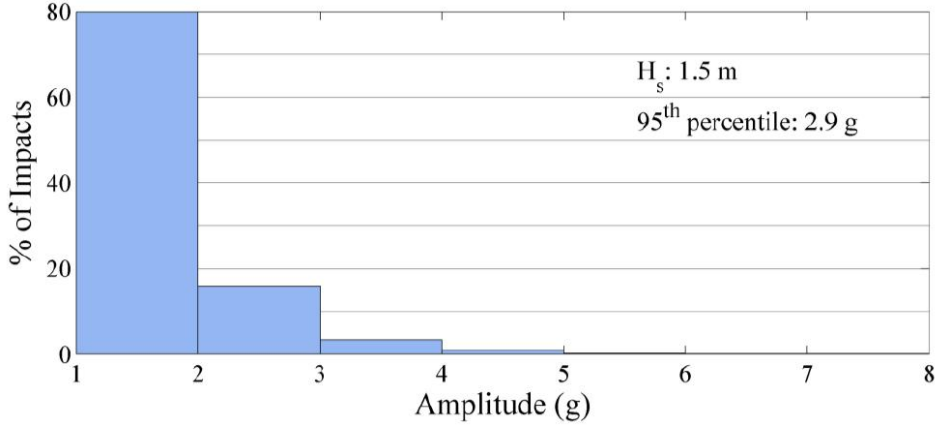
Loads

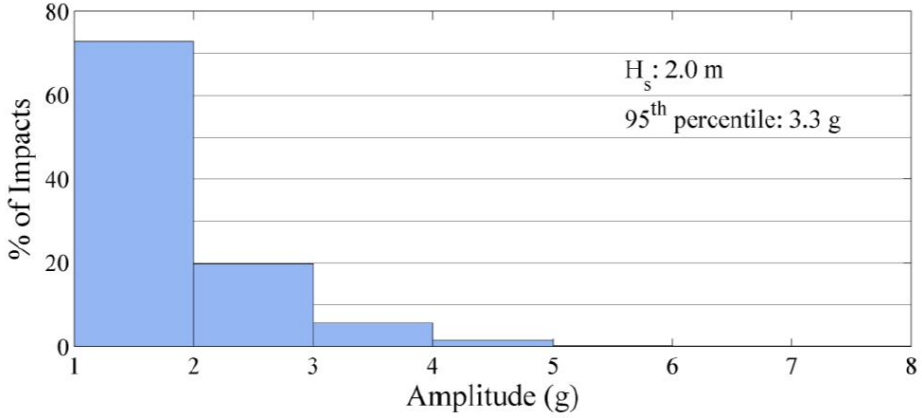
- Shock load statistics

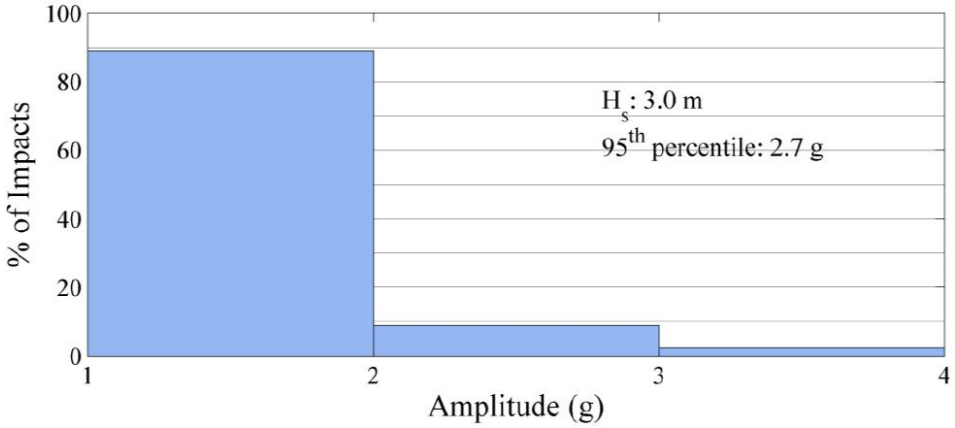


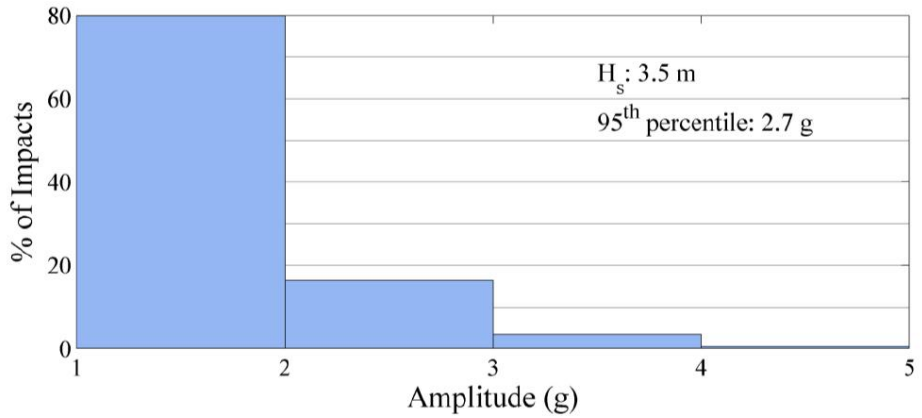
Loads

- Midships







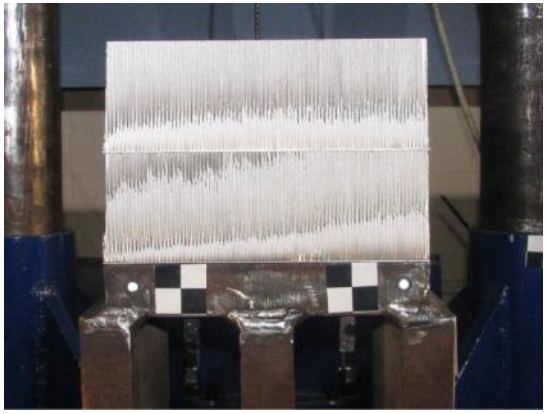


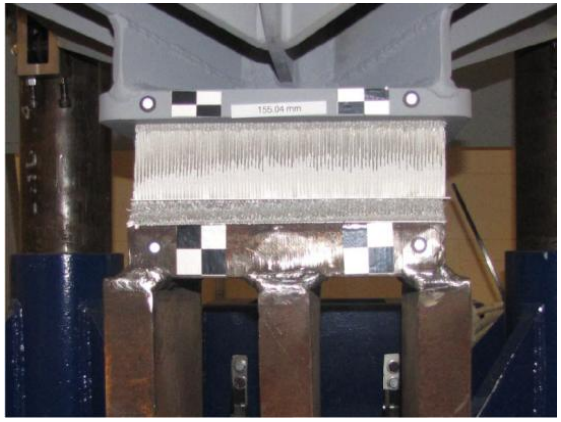
Testing

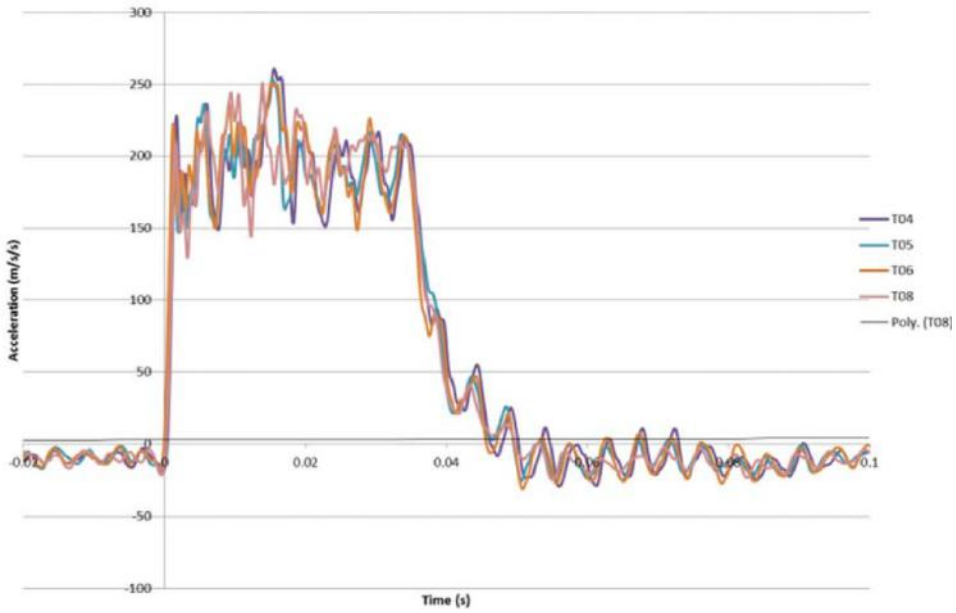
- 4 m high
- Cantilevered table
- Low friction bearings
- Winch to raise/lower
- IED protection
- Exploratory testing

Testing

- Aluminum honeycomb

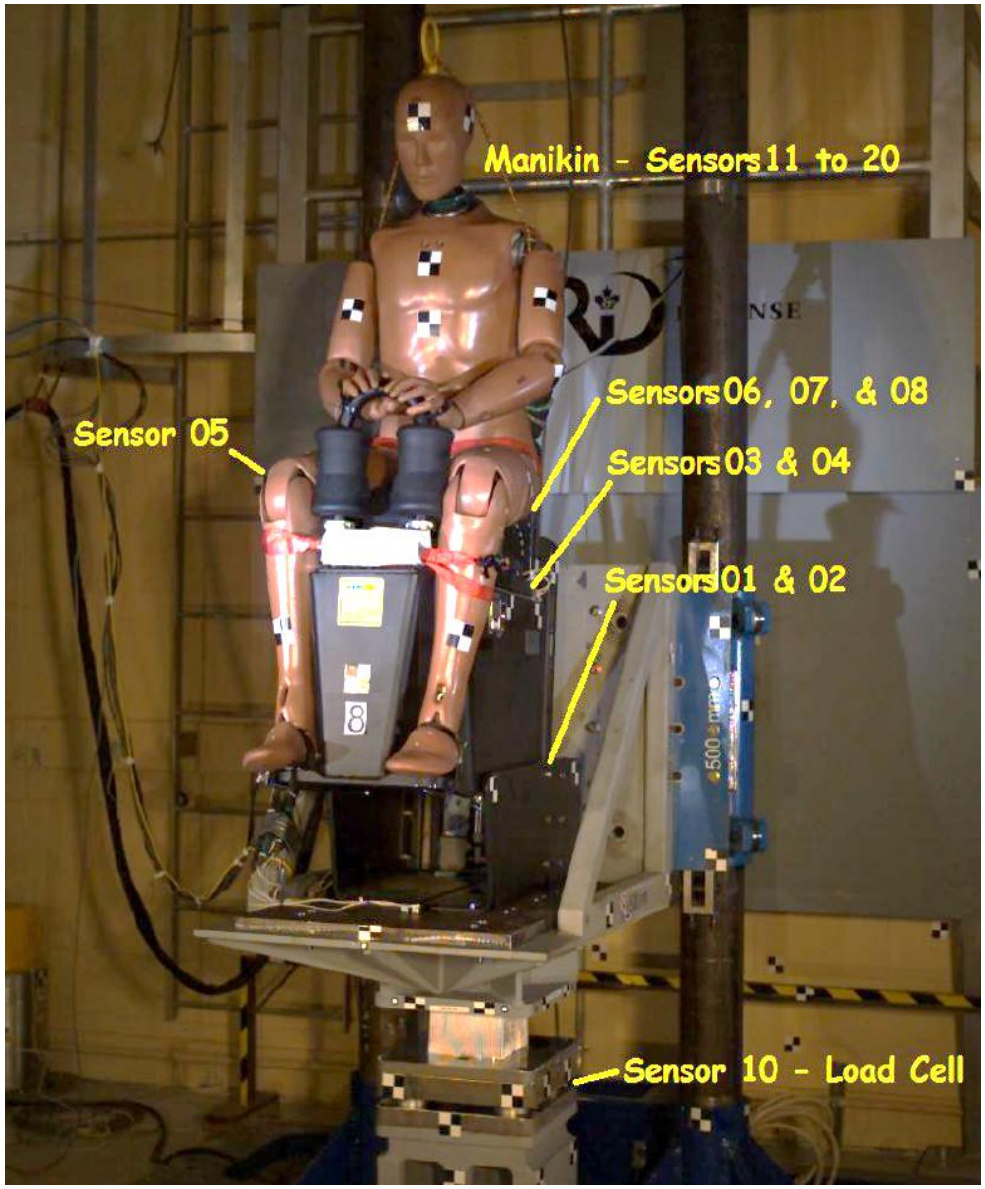




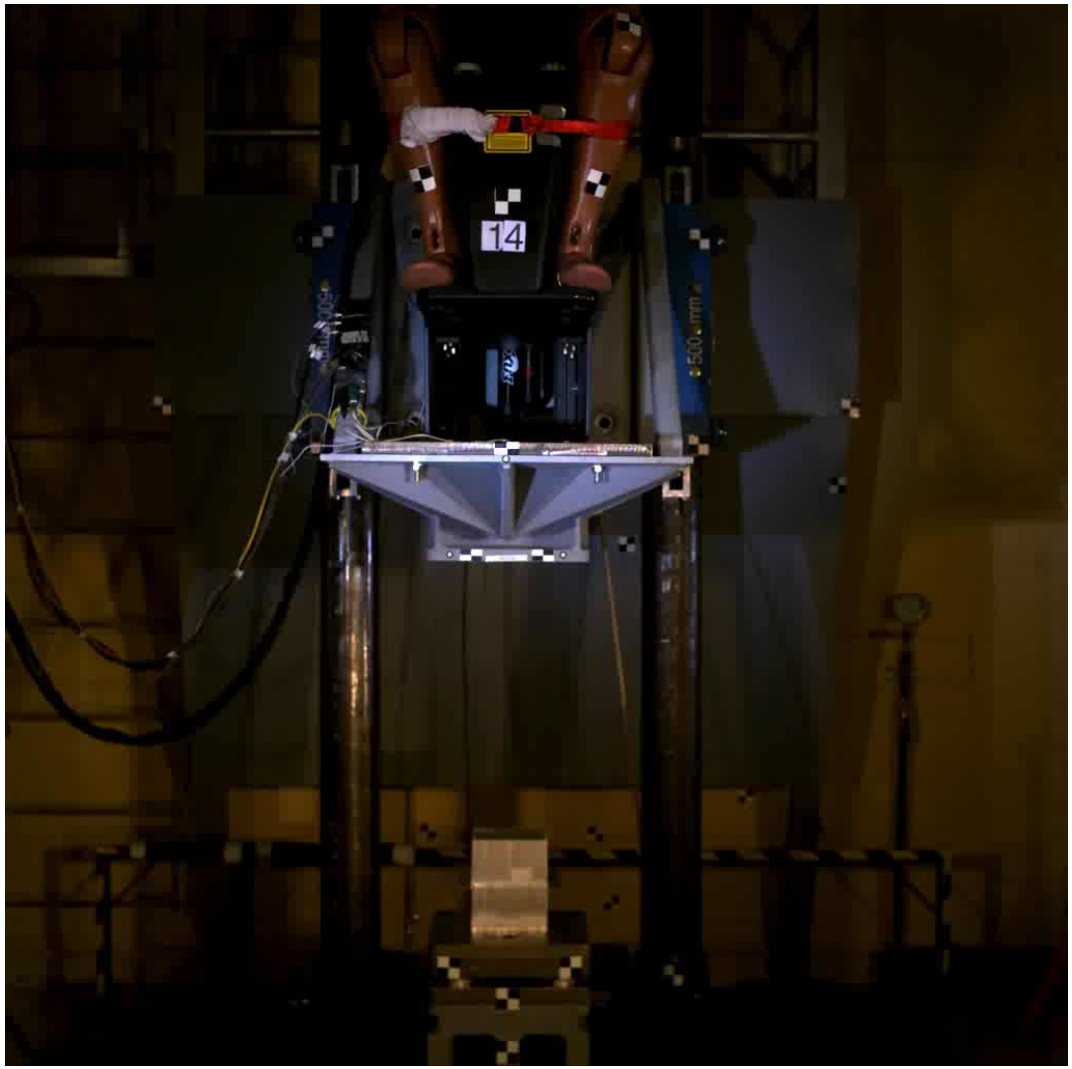


Testing

- Hybrid III ATD
  - 50th percentile male
  - 172 lbs
- Instrumentation
  - Accelerometers
  - Load cells
  - High-speed video
  - Still images
- Jockey-style seats



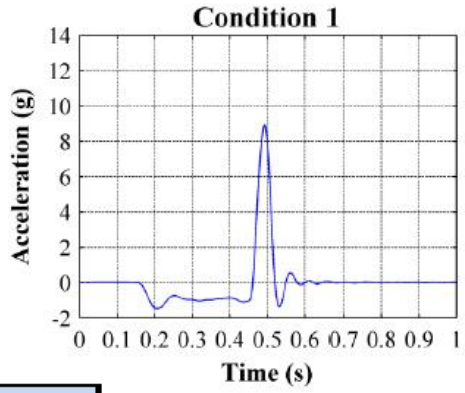
Testing

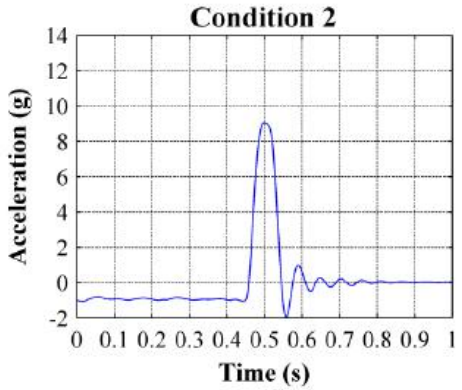


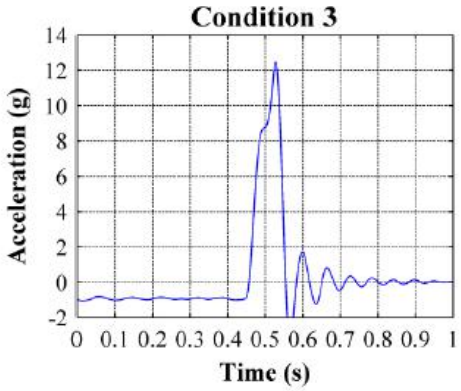
Testing

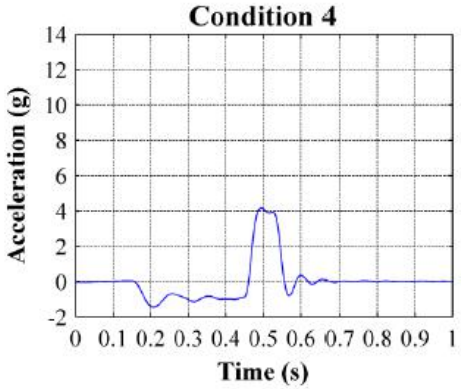
- Load conditions

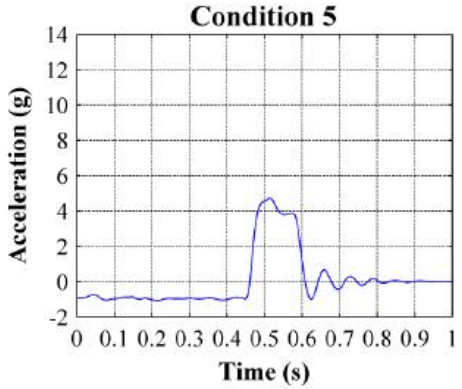
Load Condition	Phase	Drop Height (m)	No. Layers	Area (m^2)	Layer Thickness (mm)	Density (lb/ft^3)	Peak Accel. (g)	Duration (ms)
1	2,3,4	0.836	1	0.0292	101.6	4.5	8.91	60
2	2,3,4	1.735	2	0.0292	101.6	4.5	9.05	87
3	2,3,4	2.931	3	0.0292	101.6	4.5	12.47	97
4	4	0.836	2	0.0691	101.6	1.6	4.15	96
5	4	1.735	4	0.0691	101.6	1.6	4.70	147





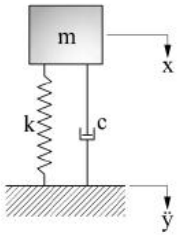






Evaluation

- Dynamic Response Index (DRI)
  - Maximum spinal compression
- Vibration Dose Value (VDV)
  - ISO 2631 – whole body vibration
- R-value
  - ISO 2631 – Vibration containing shocks
- Modified R-value
  - Greater range of acceleration
  - Age and sex
  - % risk of injury
- SEAT
  - % of shock load transmitted



$$VDV = \left(\int_0^T a^4(t)\,dt\right)^{1/4}$$

$$D_z = \left[\sum_i A_{iz}^6\right]^{1/6}$$

$$SEAT(\%) = 100 * VDV_{seat} / VDV_{deck}$$

Results

- Rank Aggregation

Seat	Load Condition					Sum
	1	2	3	4	5	
A	9	11	15	12	13	60
B	15	11	8	7	8	49
C	6	8	7	11	9	41

Seat	Injury Criterion					Sum
	DRI	VDV	R-value	Modified R-value	SEAT	
A	11	14	11	10	14	60
B	14	7	10	10	8	49
C	5	9	9	10	8	41

Conclusions and Discussion

- Repeatable test procedure
- Reasonable representation of measured loads
- Seat A performed best for the drop conditions tested
- Multiple criteria for evaluation of shock mitigation effectiveness
- Test and evaluation of semi-active and active seats

Limitations

- Only seats with linear suspensions tested
- Only pure vertical impacts tested – No lateral forces
- No living subjects in the seats - Not possible for ethical reasons
- This test method cannot be used for testing performance of seats made for occupants feet to be in contact with the deck and legs used as part of the suspension
- Multiple criteria for evaluation of shock mitigation effectiveness are not proven to be related to risk of injury

Conclusions and Discussion

- Future work
  - Load characterization
  - Mathematical modelling/simulation
  - Repeated impact SISTR