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Ride Quality Index – A New Approach to Quantifying the Comparison of Acceleration Responses of High Speed Craft

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Outline

Dr. Paul Rispin
ONR 331

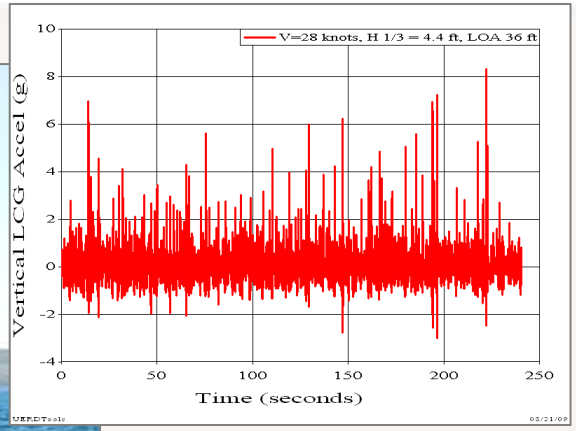
- Background
- Objective
- Repeatable $A_{1/n}$ Calculations
- Ride Quality Index
- Wave Slam Damage Potential
- Example Comparisons
- Summary

Background

- Historical perspective (1950's – early 1970's)
  - Passenger comfort studies for airplanes, cars, trains
  - Ride quality linked to vibrations, temperature, noise
  - RMS acceleration values used to quantify vibration amplitudes
  - Applied to displacement hulls, surface effect ships, hydrofoils

- NSWCCD mid-1970's: RMS values reported not applicable when craft motions include shocks or impulsive velocity changes
  - Dissatisfaction with general lack of ride quality data
  - Lack of fully satisfactory criteria for judging ride quality in rough seas
  - No standard process for acquiring and processing data

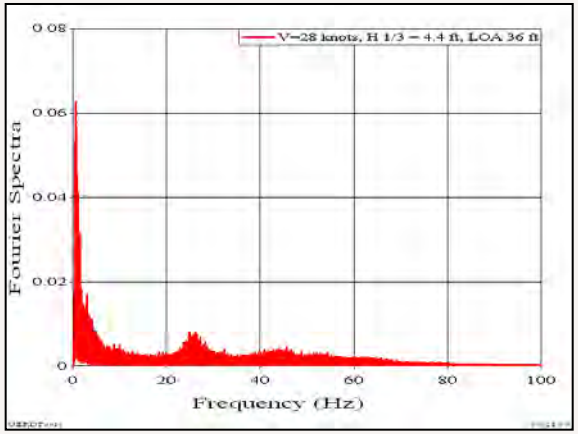
Objective



To present a simplified approach to quantifying ride quality when comparing wave impacts for different craft, different sea states, different speeds, or different gage locations.

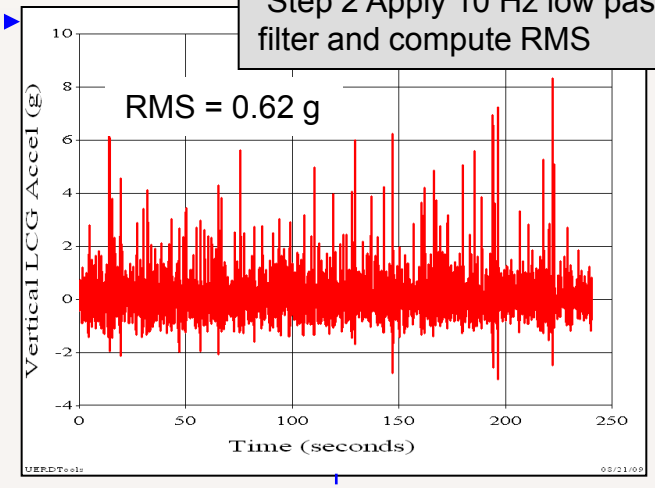
$A_{1/n}$ Calculation Process
Unambiguous statistical calculations

Step 1 Compute spectrum of unfiltered record



Use spectrum to confirm 10 Hz filter criteria and ½ second time criteria

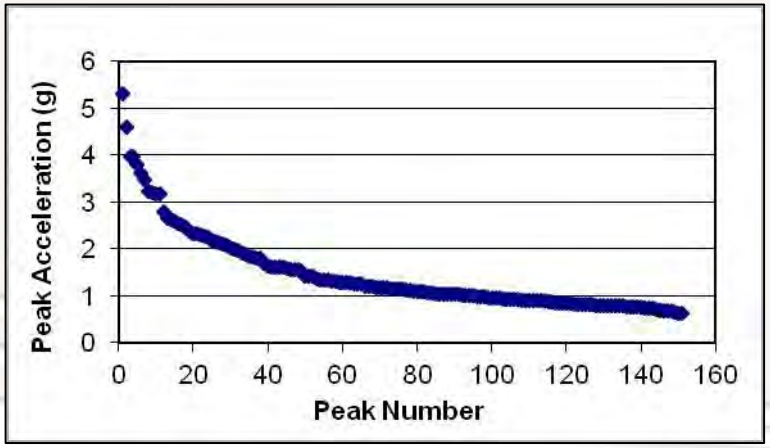
Step 2 Apply 10 Hz low pass filter and compute RMS



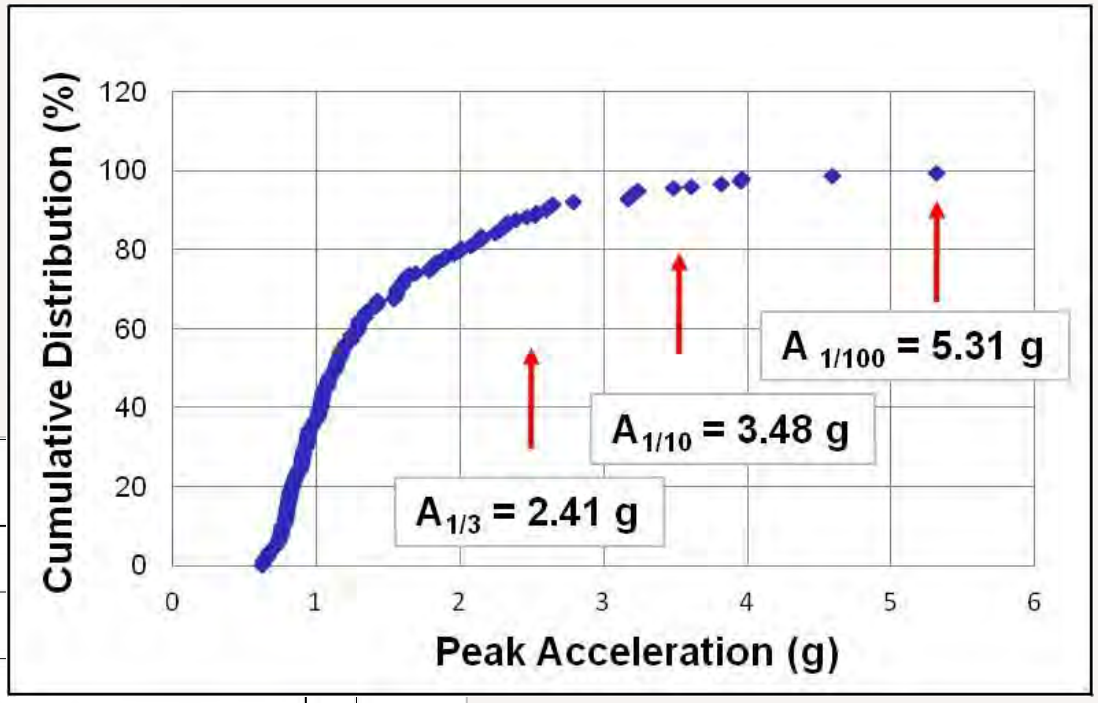
Step 3 Extract peaks with PKT algorithm using RMS vertical threshold and ½-second time threshold

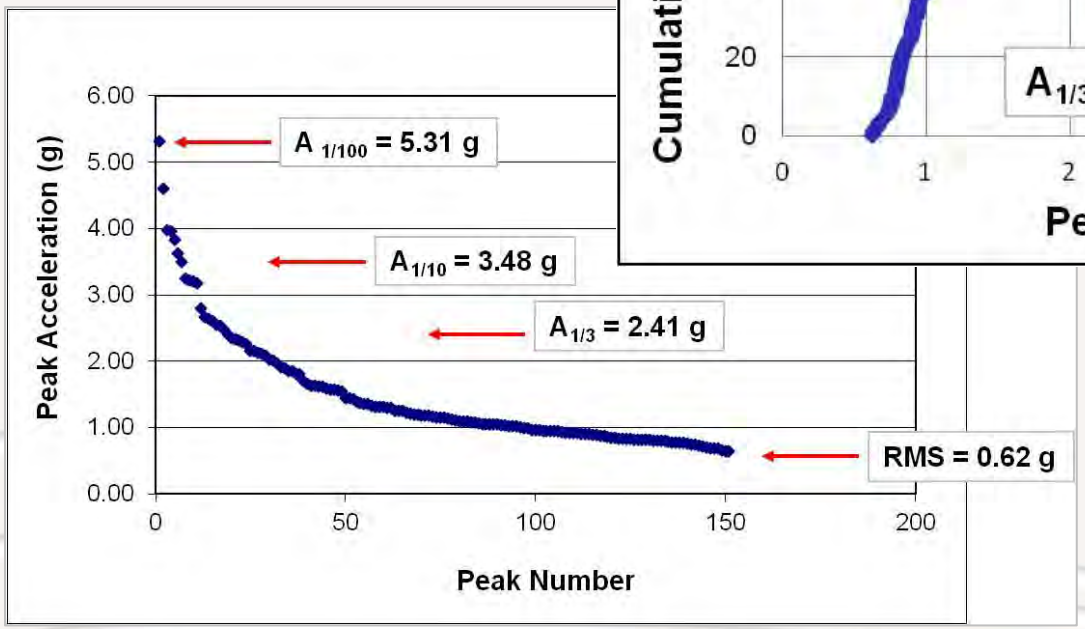
Step 4 Compute statistical values

5.31g = $A_{1/100}$
3.48g = $A_{1/10}$
2.41g = $A_{1/3}$
0.62g = RMS

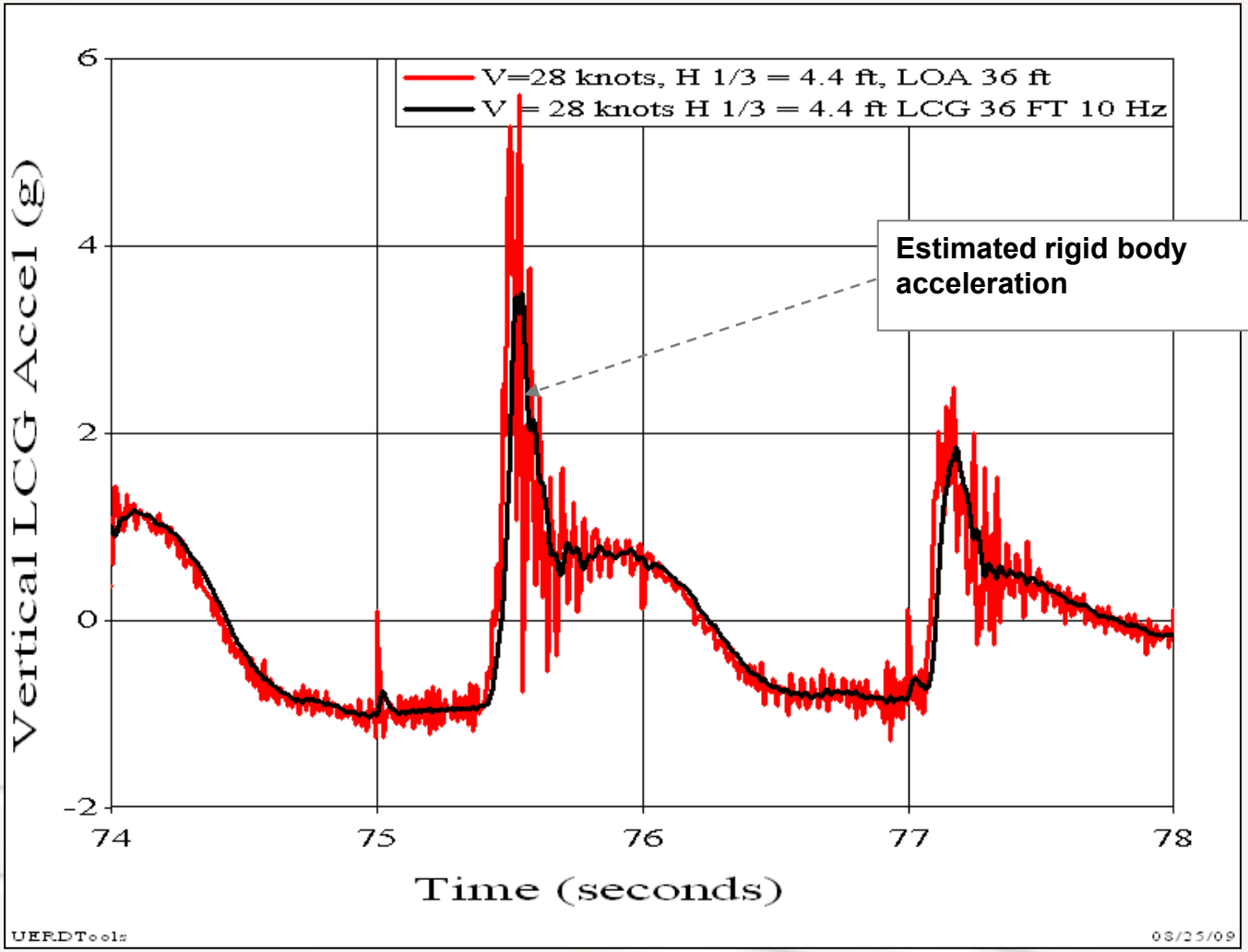


Average $A_{1/n}$ Accelerations





Filtered vs Unfiltered Wave Encounters



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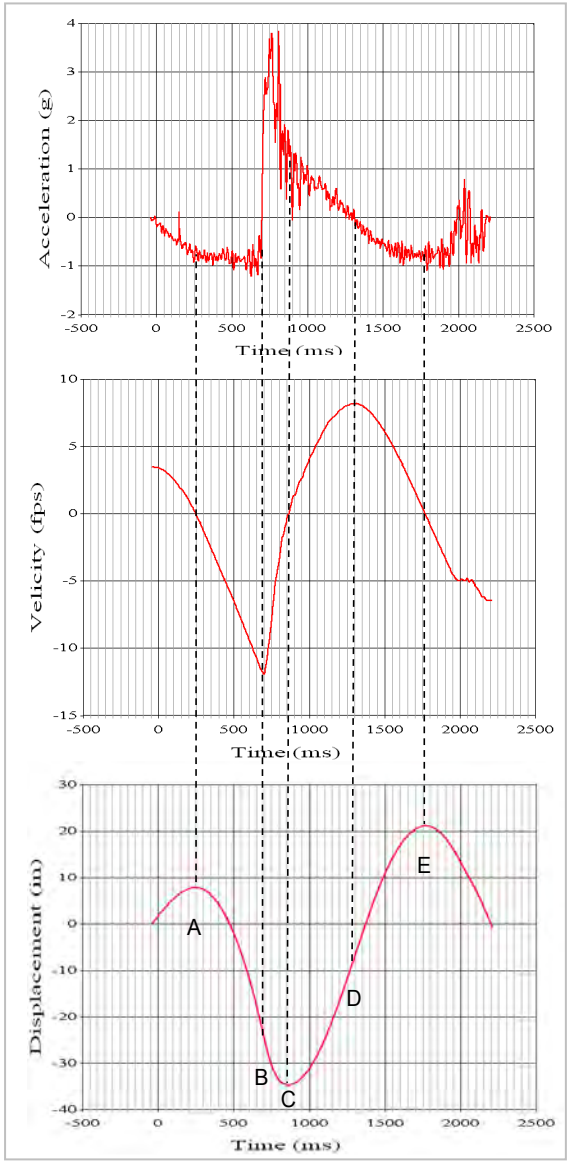
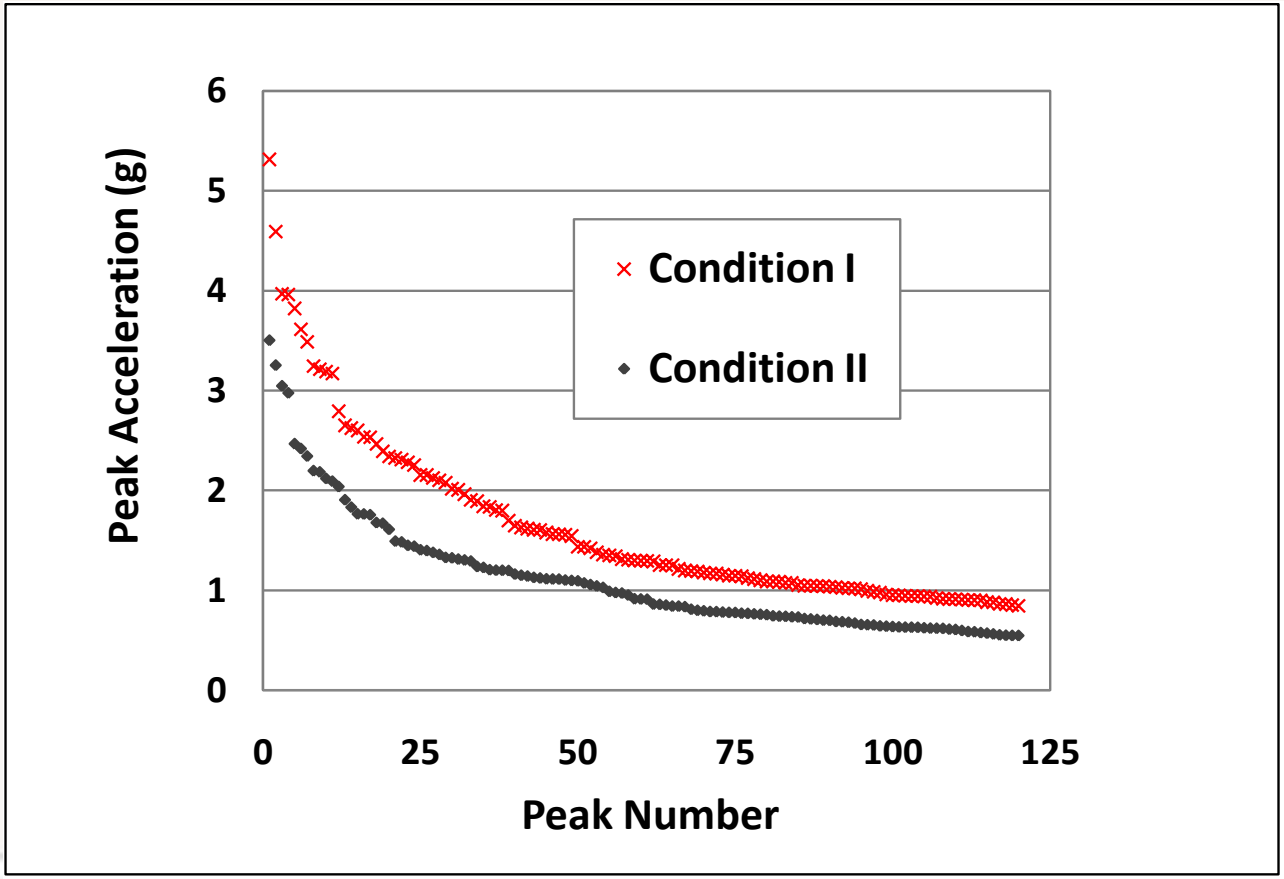
Single Impa

Time	Response
A to B	• Close to gravity free-fall (- • Estimate of drop height pr impact
B	• Maximum downward veloc • Time of initial water impac
B to C	• Craft moving down in wat • Maximum loading phase • Wave slam period
C	• Time of maximum downwa • Instantaneous velocity = 0 • Loading reduced to ambie
C to D	• Upward hydro-dynamic fo • Upward buoyant force • Upward thrust vector • Force upward stops at D

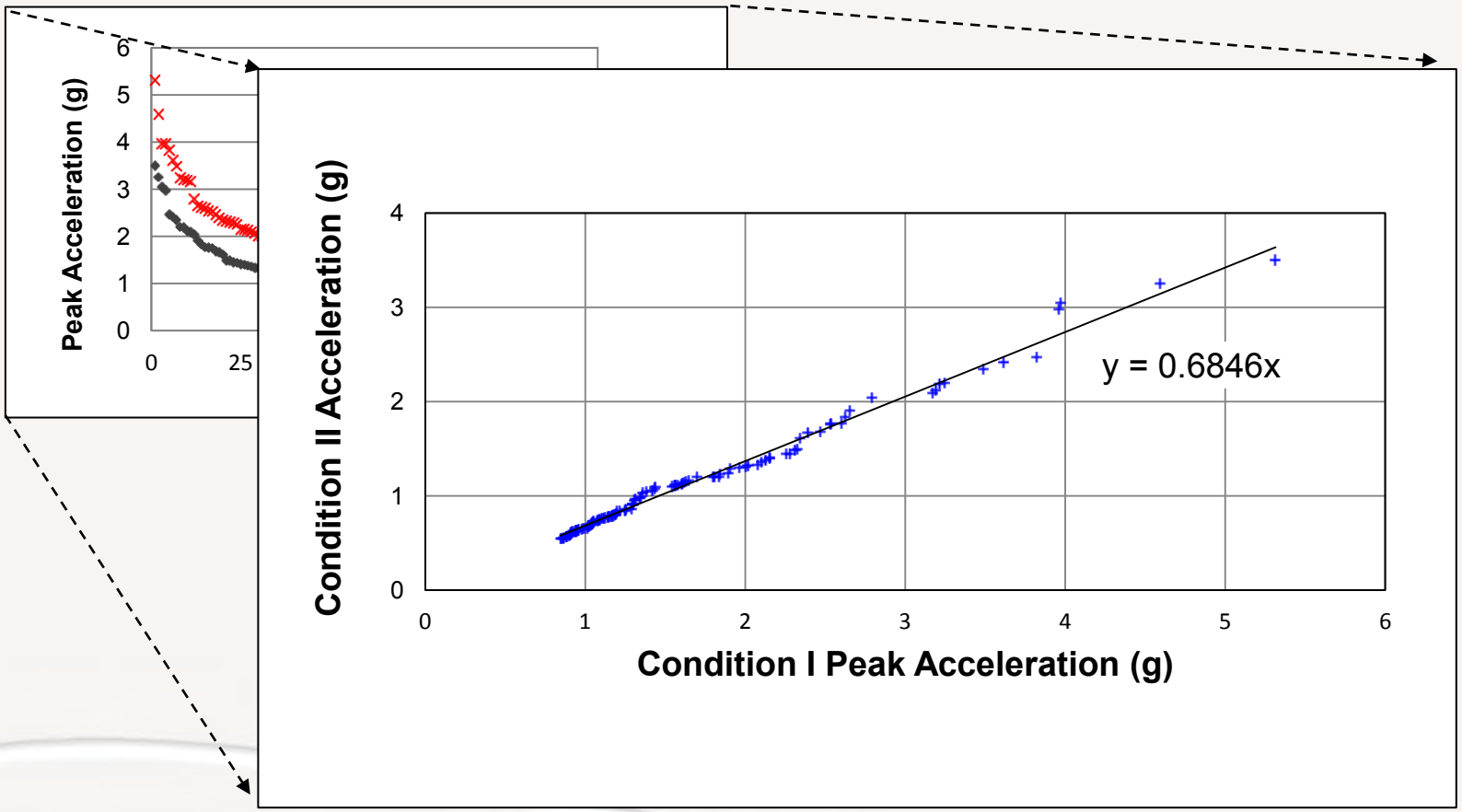


Peak Acceleration Comparison



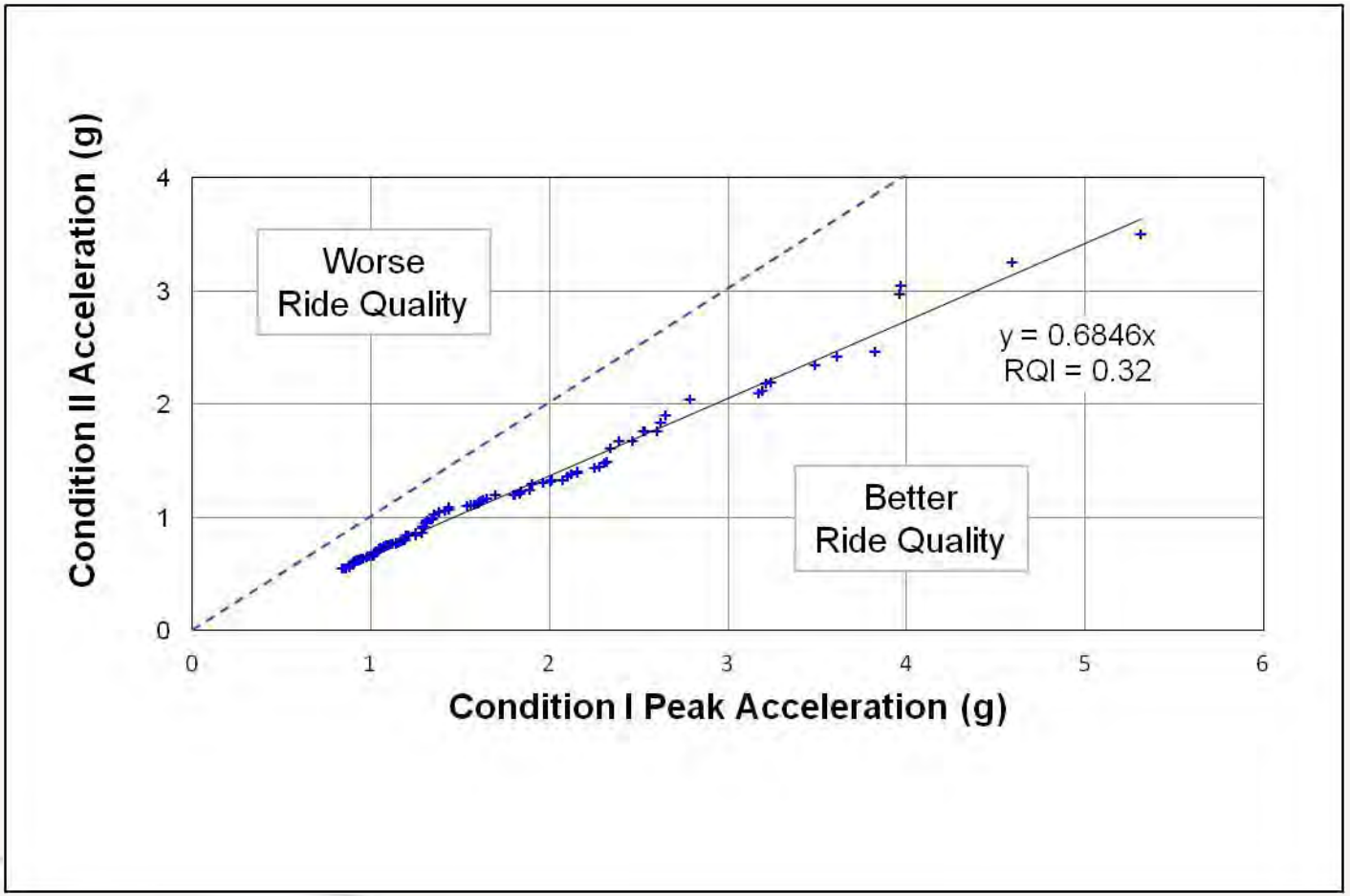
Test Condition Variables: different craft, speeds, wave heights, gage locations

Different Comparison Format



The least squares linear fit has a zero intercept

Ride Quality Index



$$Ride\ Quality\ Index\ (RQI) = 1 - \frac{\Delta A_{ConditionII}}{\Delta A_{ConditionI}}$$

Why "Acceleration Ratio" ?

Damage Categories

Structural Damage
Equipment malfunction or failure
Crew discomfort or injury

$$(Damage\ Potential)_{Shock} \propto (\Delta\ Rigid\ \ Body\ Velocity)$$

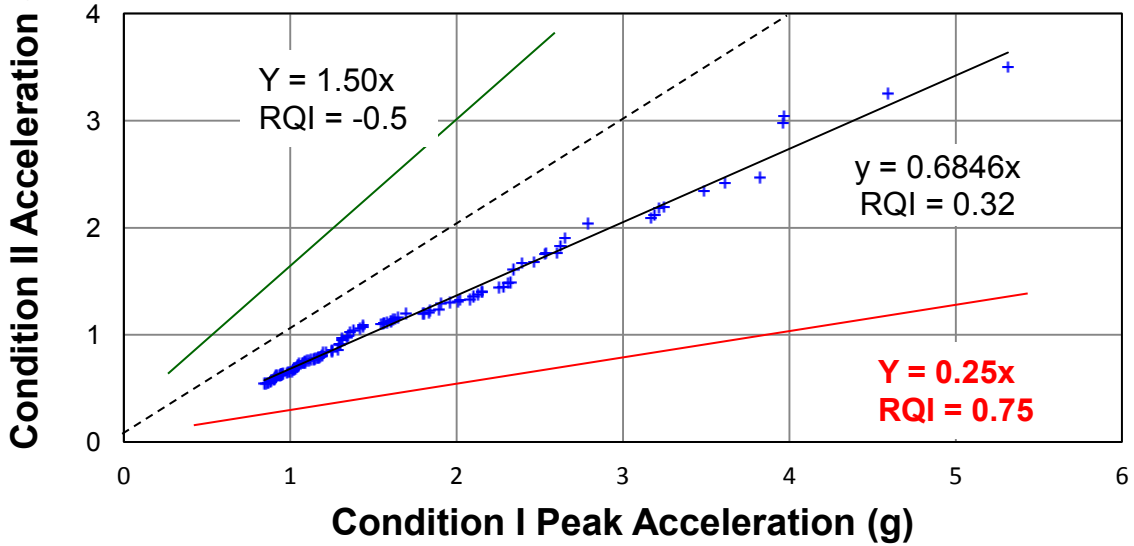
$$\frac{A_{RBII}}{A_{RBI}} \approx \frac{\Delta V_{RBII}}{\Delta t_{RBII}} \Big/ \frac{\Delta V_{RBI}}{\Delta t_{RBI}}$$

$$If\ \ \Delta t_i\ is\ relatively\ \text{constant}\ldots \qquad then\ \frac{A_{II}}{A_I} \approx \frac{\Delta V_{RBII}}{\Delta V_{RBI}}$$

$$RQI = 1 - \frac{A_{II}}{A_I} = 1 - \frac{\Delta V_{II}}{\Delta V_I} \propto \frac{1}{Damage\ Potential}$$

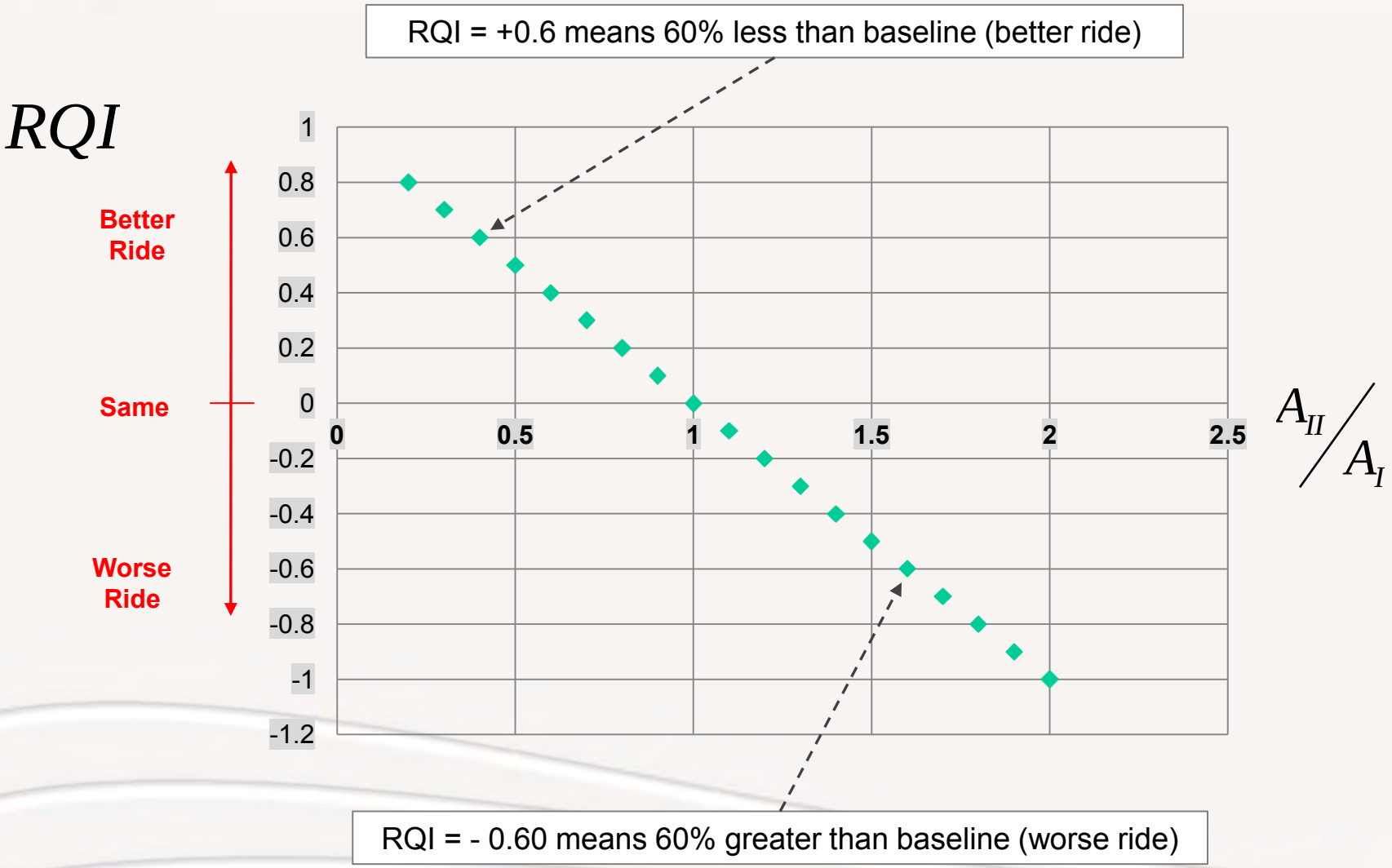
Ride Quality Index = *f (Damage potential)*$^{-1}$

$$Ride\ Quality\ Index\ (RQI) = 1 - \frac{\Delta A_{ConditionII}}{\Delta A_{ConditionI}}$$

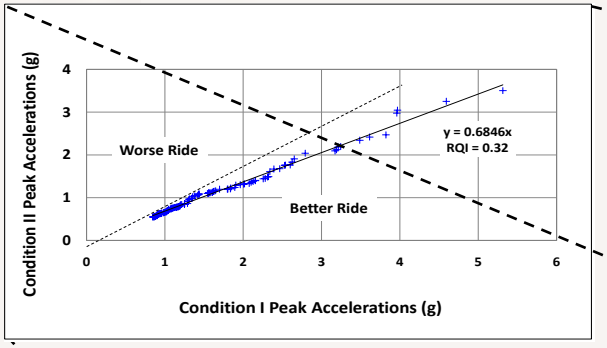


$$\frac{A_{II}}{A_I} \uparrow \rightarrow Damage\ Potential \uparrow \rightarrow RQI \downarrow \qquad \frac{A_{II}}{A_I} \downarrow \rightarrow Damage\ Potential \downarrow \rightarrow RQI \uparrow$$

RQI vs Acceleration Ratio

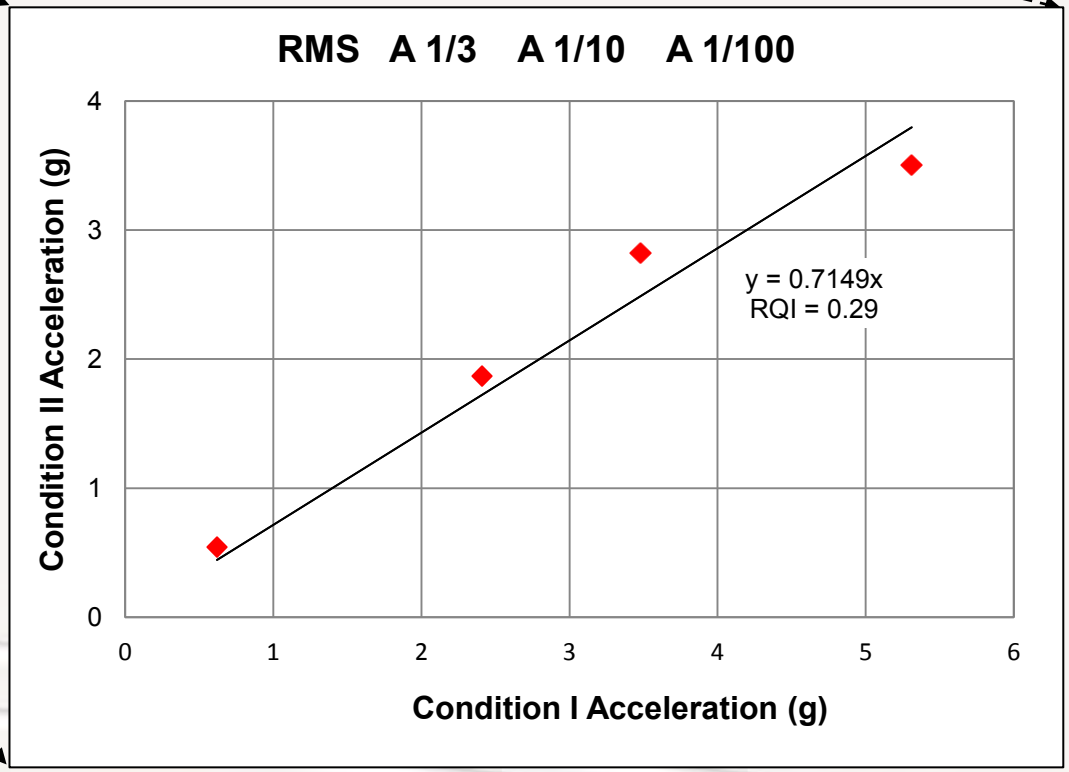


Ride Quality Index Using $A_{1/n}$ Ratios

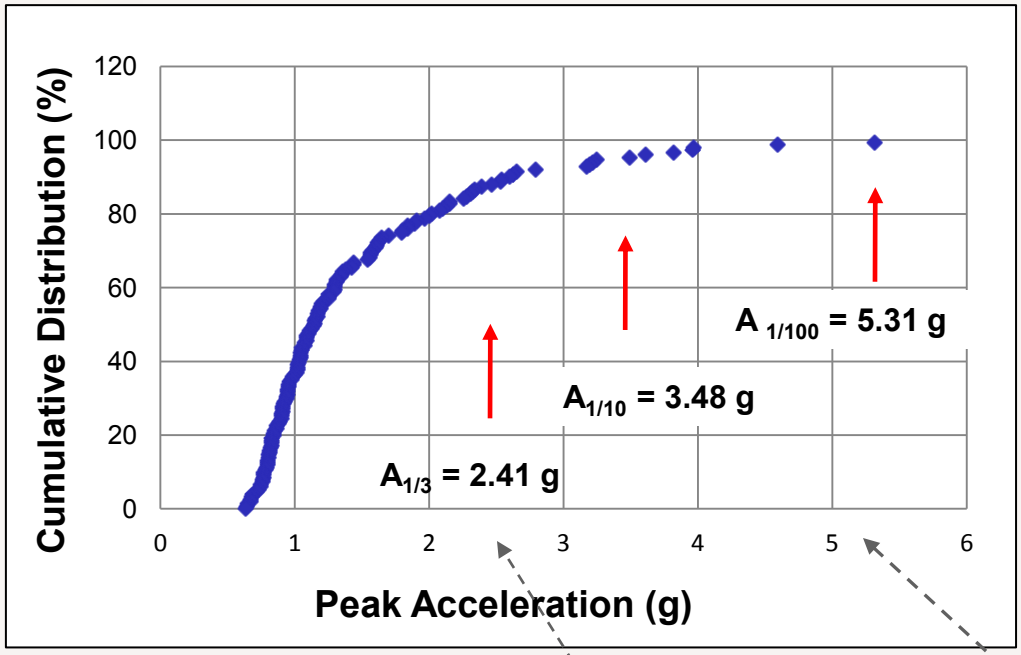


$$RQI_{1/10} = 1 - \frac{\left(A_{1/10\,II} - 0\right)}{\left(A_{1/10\,I} - 0\right)}$$

Test	Condition I	Condition II	Ride Quality Index
A 1/100	5.31 g	3.50 g	0.34
A 1/10	3.48 g	2.82 g	0.19
A 1/3	2.41 g	1.87 g	0.24
RMS	0.62g	0.54g	0.13
1-Slope	na	na	0.29



Simple Damage Mechanisms



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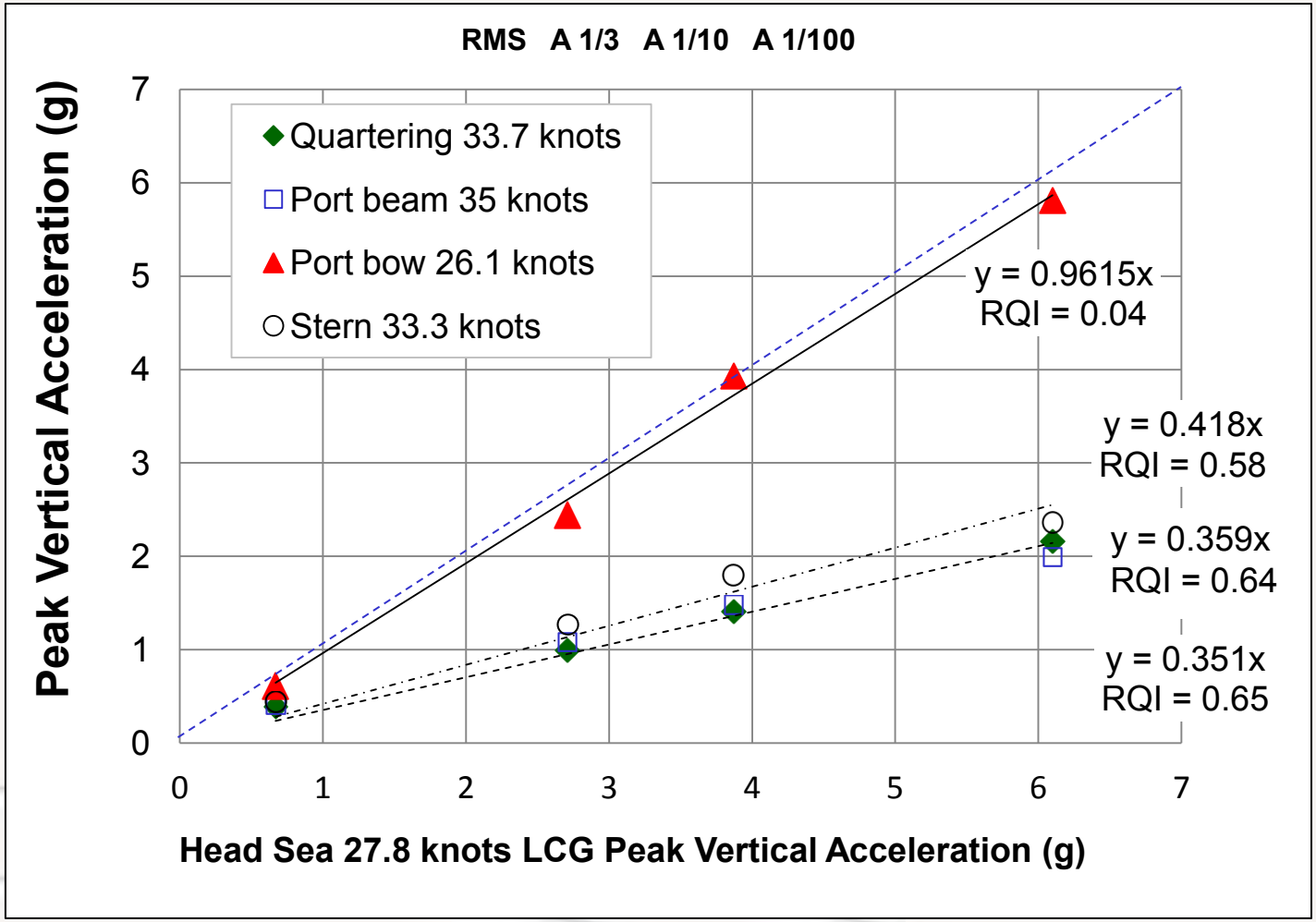
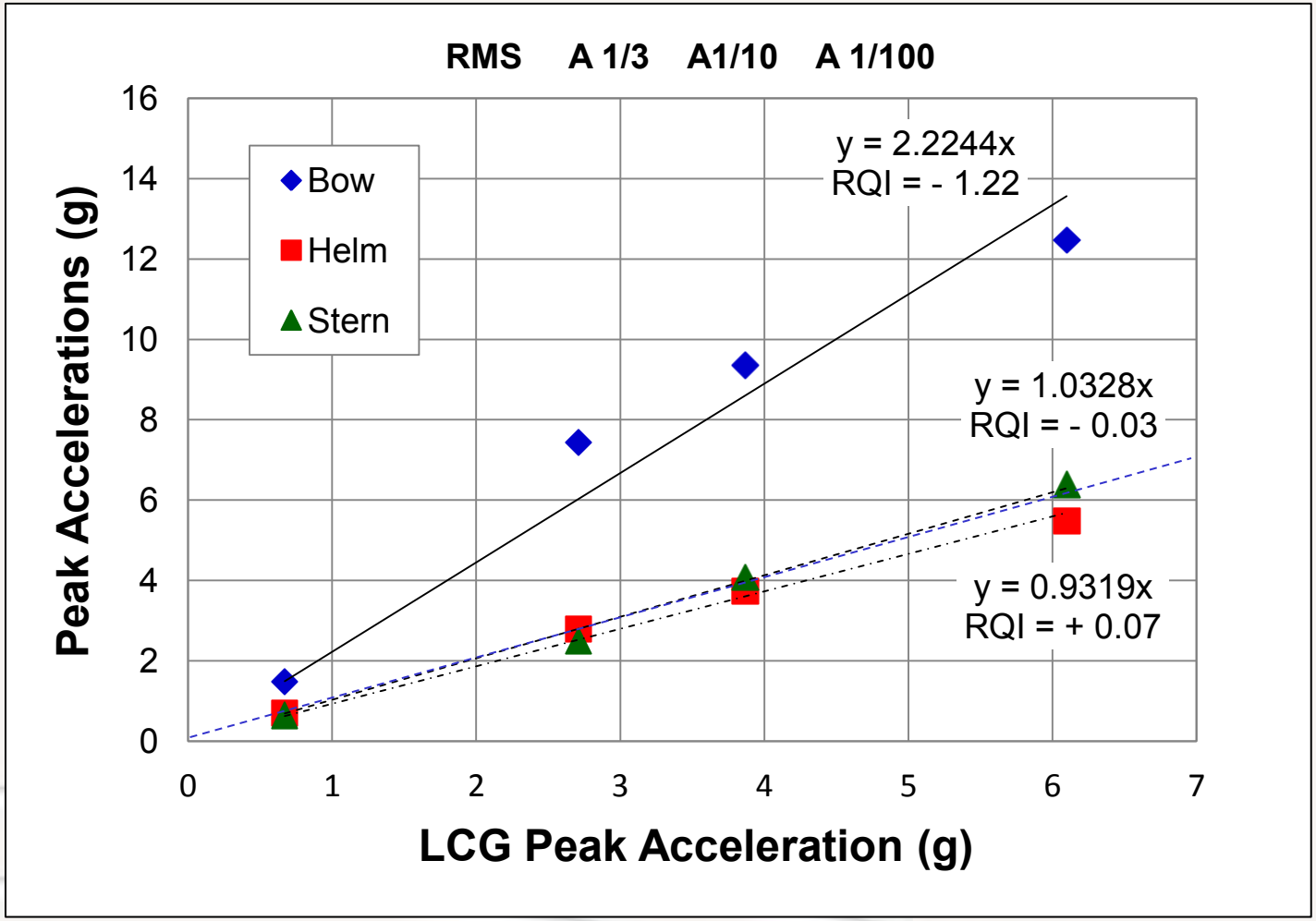
Failures due to severe (large amplitude) wave slams (shocks) could be caused by material over stresses or disconnects

Failures due to cyclic lower amplitude wave slams (shock) could be caused by electrical disconnects of plugs, sockets, or circuit cards

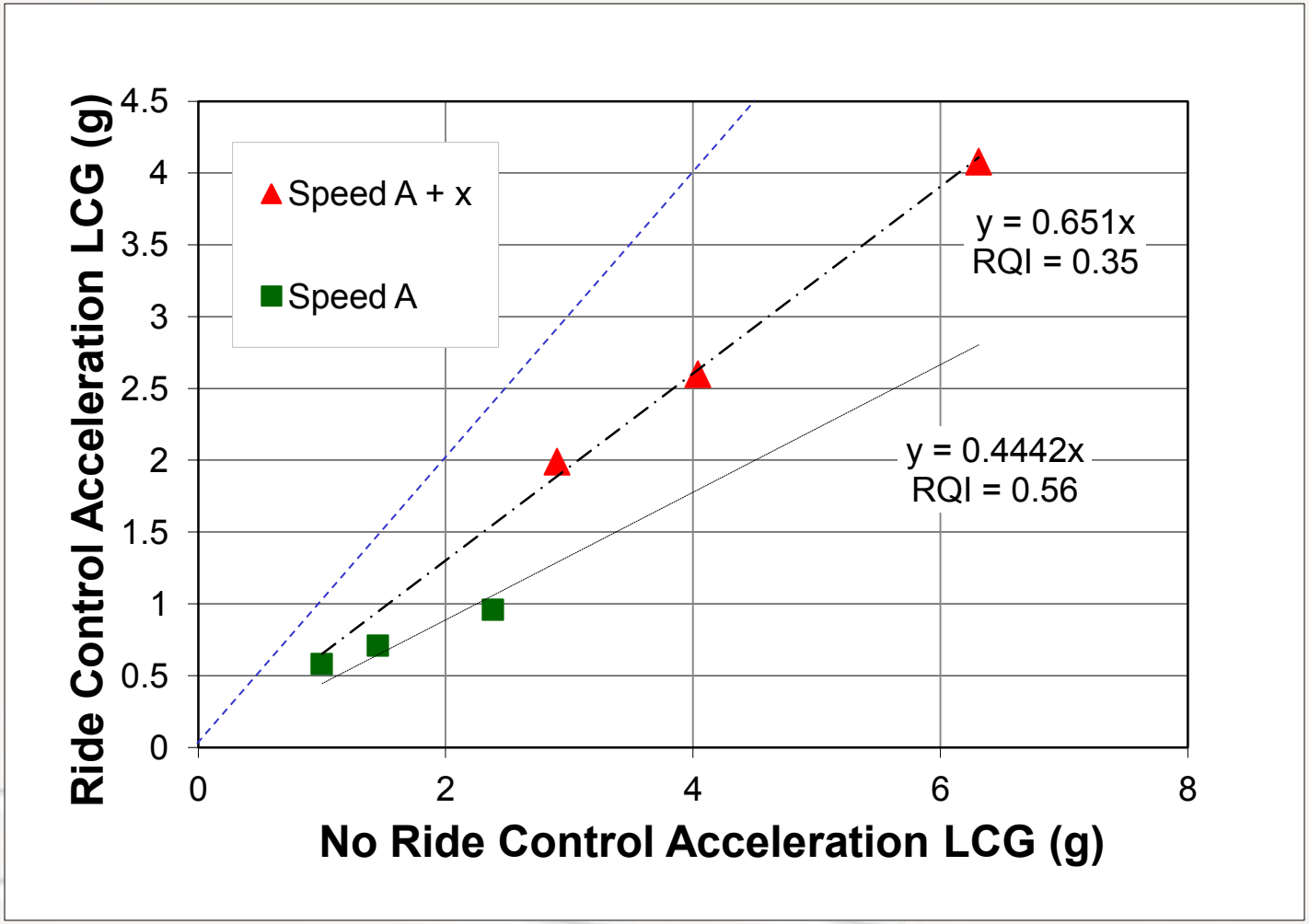
Example: Same Craft Different Headings



Example: Same Craft Different Gage Locations



Example: Two Craft - Ride Control Comparison



Observations

- Use of RQI requires consistent data processing
  - Generalized $A_{1/n}$ process
- New approach
  - Use of all peak accelerations
  - Or, use of all statistics (RMS, $A_{1/3}$, $A_{1/10}$, $A_{1/100}$), not one level
- Also applicable to pitch, roll, pitch or roll rates
- Useful to quantify a skilled operators perception
- Compare craft responses regardless of the source of the data, when generalized $A_{1/n}$ process used

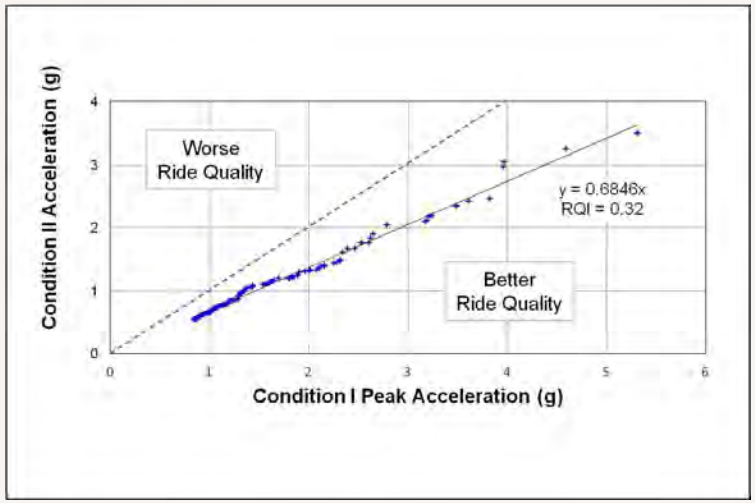
Summary

- Applied a 4-step computational process for repeatable $A_{1/n}$ calculations

- Introduced a simple Ride Quality Index
  - New combined use of all peaks, RMS, $A_{1/3}$, $A_{1/10}$, $A_{1/100}$
  - Proportional to wave slam (shock) damage potential
  - Cumulative damage or single-severe slam affects
  - Useful tool for better/worse ride quality comparisons

- Use of standardized $A_{1/n}$ calculation and RQI may foster future comparisons of ride quality of different craft or different test conditions regardless of the source of the data

Questions



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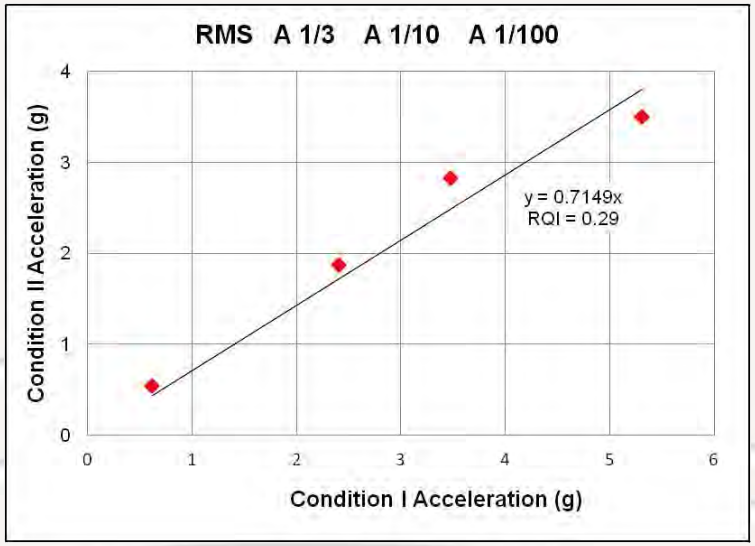

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