

# Section 4

IMPULSE AND FORCE DURATION TO REPLACE ENERGY  
AND FORCE AS FRANGIBILITY CRITERIA

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# Recommendations

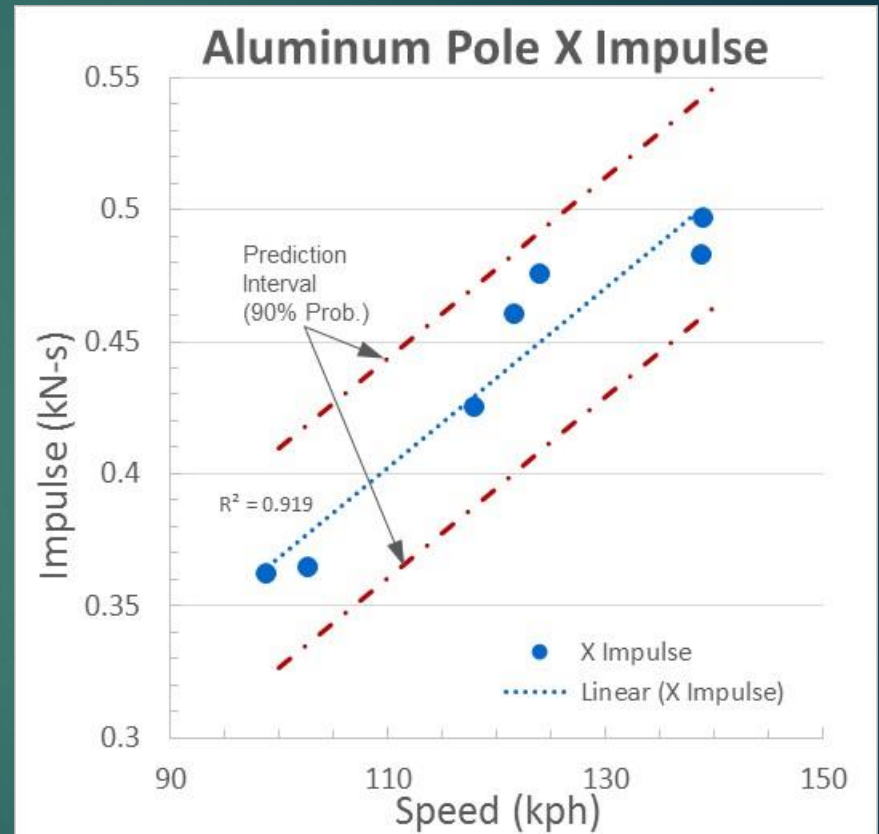
- ▶ Replace energy criteria with impulse
- ▶ Research force duration criteria as a possible alternative to peak force

## ▶ ICAO

- ▶ “4.1.1 Impact may affect flight safety in three ways:
  - a) the aircraft may lose momentum;
  - b) the aircraft may change direction; and
  - c) the aircraft may suffer structural damage.”
- ▶ “4.1.2 The amount of momentum lost is mathematically governed by the integral of force over time.”

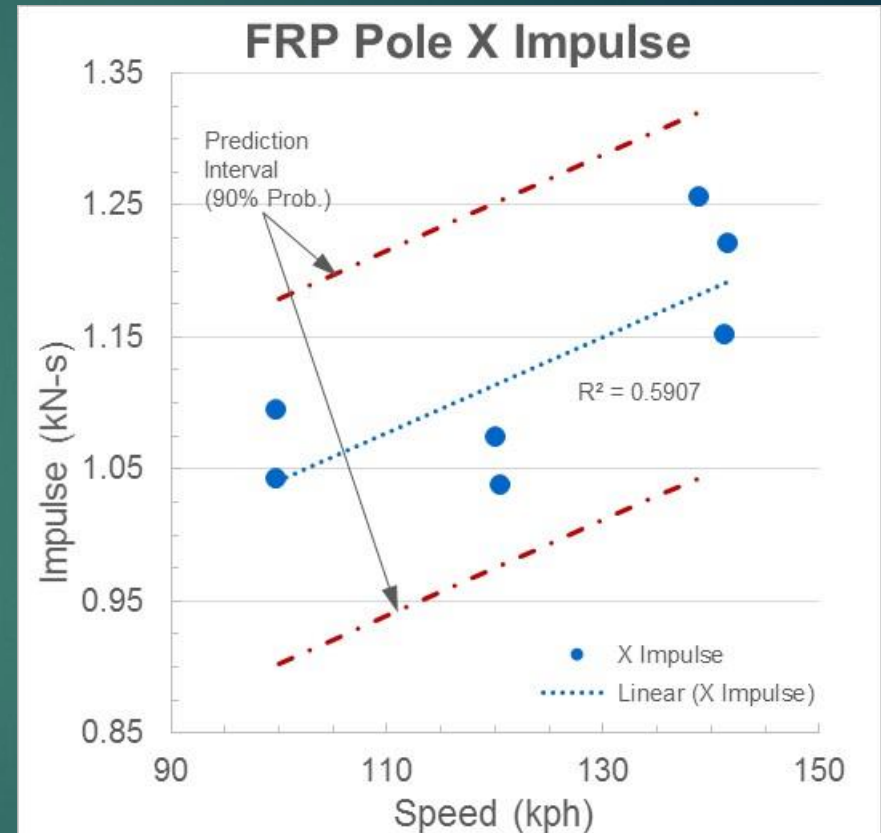
# Impulse

- ▶ Aluminum poles
  - ▶ Relatively small variation
  - ▶ Clear correlation to Speed
  - ▶ Prediction interval @ 140 kph: 0.504 kN-s  $\pm$  8.2%



# Impulse

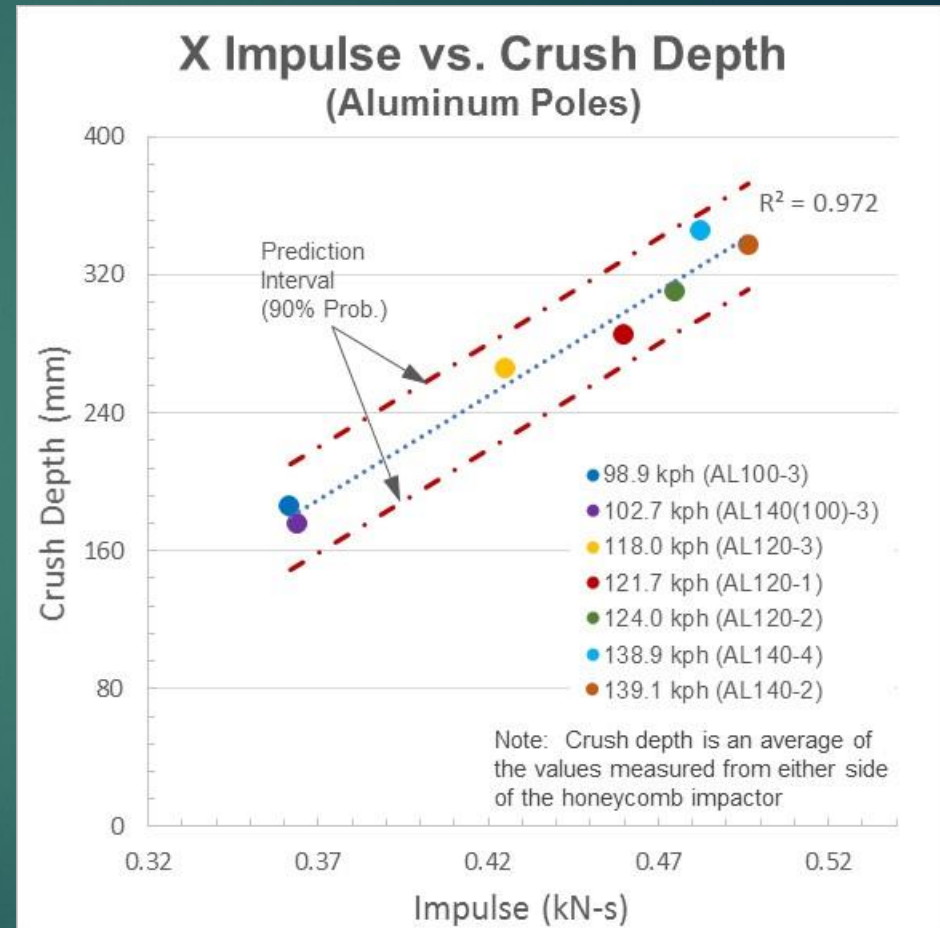
- ▶ FRP poles
  - ▶ Relatively small variation
  - ▶ Some correlation to Speed
    - ▶ More of the variation is due to sources other than speed
  - ▶ Prediction interval @ 140 kph: 1.186 kN-s  $\pm$  11.67%



# Impulse

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- ▶ Aluminum poles
  - ▶ Relatively small variation
  - ▶ Clear correlation to Crush Depth
  - ▶ Prediction interval @ 0.504 kN-s: 352 mm  $\pm$  8.4%



# Energy (Work) vs Impulse

## ▶ Review

### ▶ Energy (Work)

- ▶ Work done on pole is not accurately represented because of impactor crush
- ▶ Energy calculation only applicable to the X-direction

### ▶ Impulse

- ▶ Does not require an estimate of impactor displacement
  - ▶ Can be applied in multiple directions
  - ▶ Directly related to change in momentum of the aircraft
  - ▶ Correlation to impactor crush (wing damage)
- ▶ Limit for energy at 140 kph can be directly applied to impulse criteria



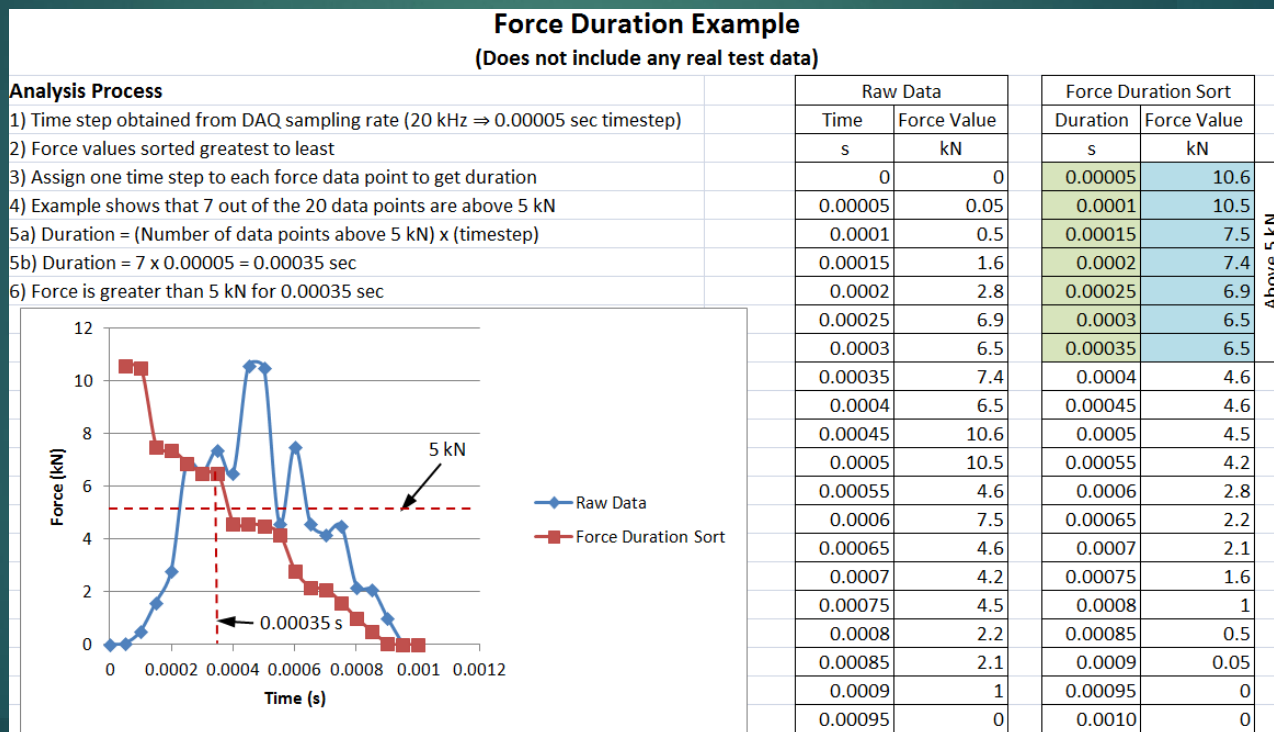
Shane Shurtliff, P.E.  
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# Force Duration

## Proposed Criteria

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- ▶ Calculating force duration is a process which analyzes the duration in which a force is applied

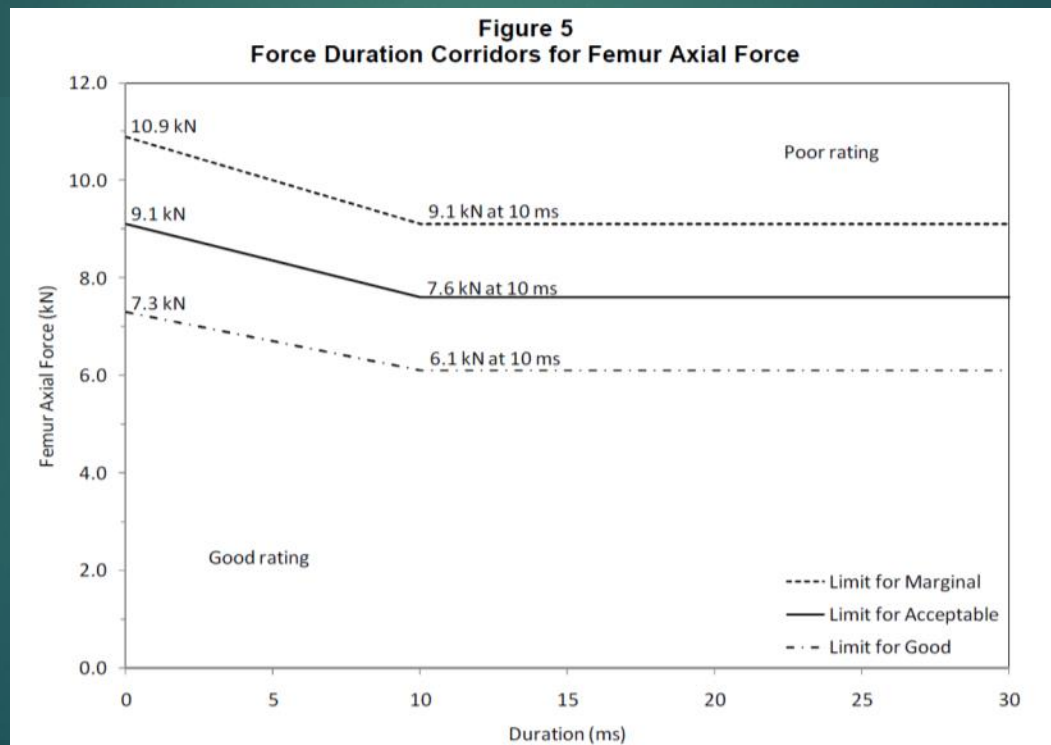


# Force Duration

## Proposed Criteria

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- ▶ The automobile industry uses force duration in many different areas of testing, but most commonly in human injury ratings

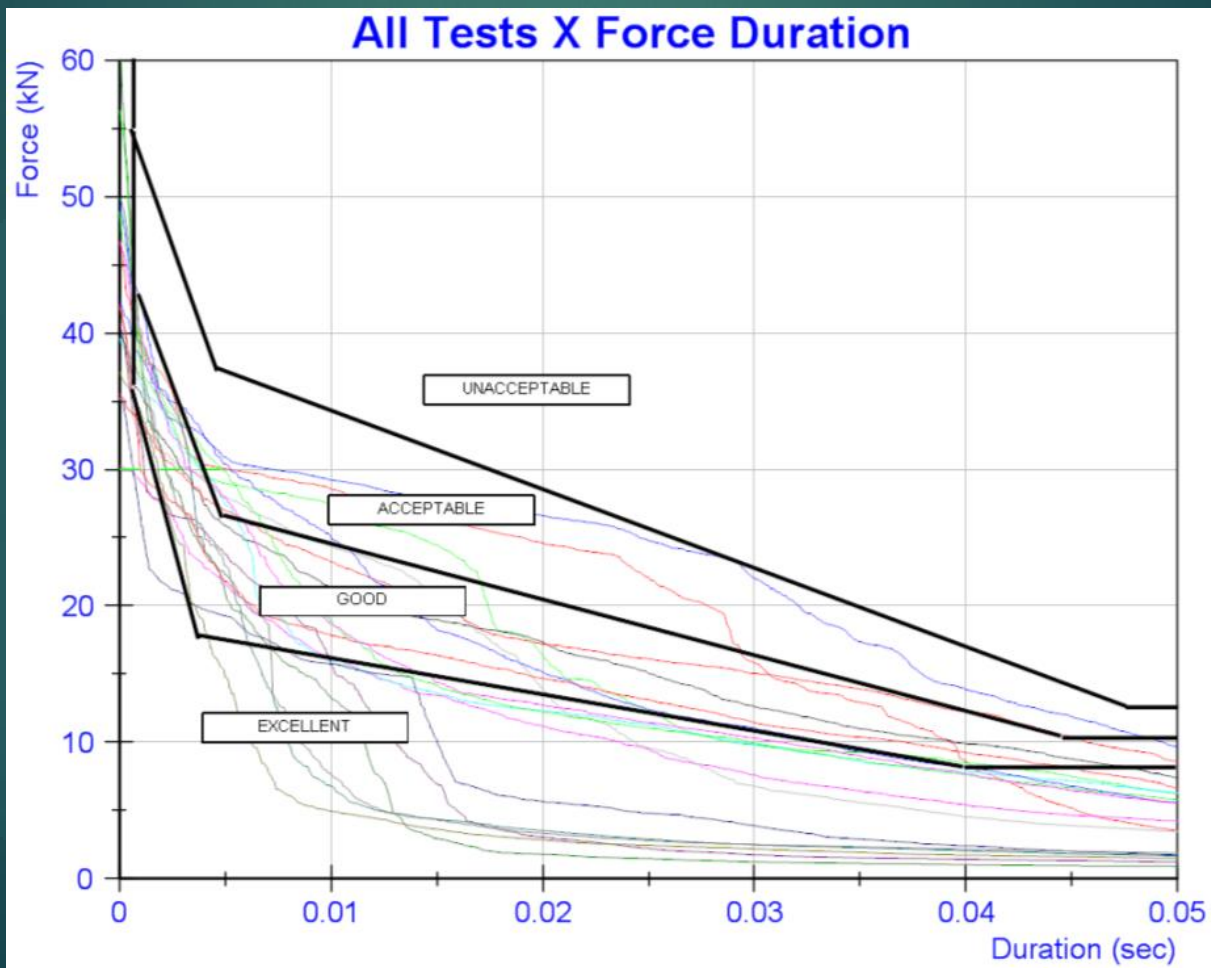


# Force Duration

## Proposed Criteria

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- ▶ X-Axis Force Duration Rating Criteria (Example)

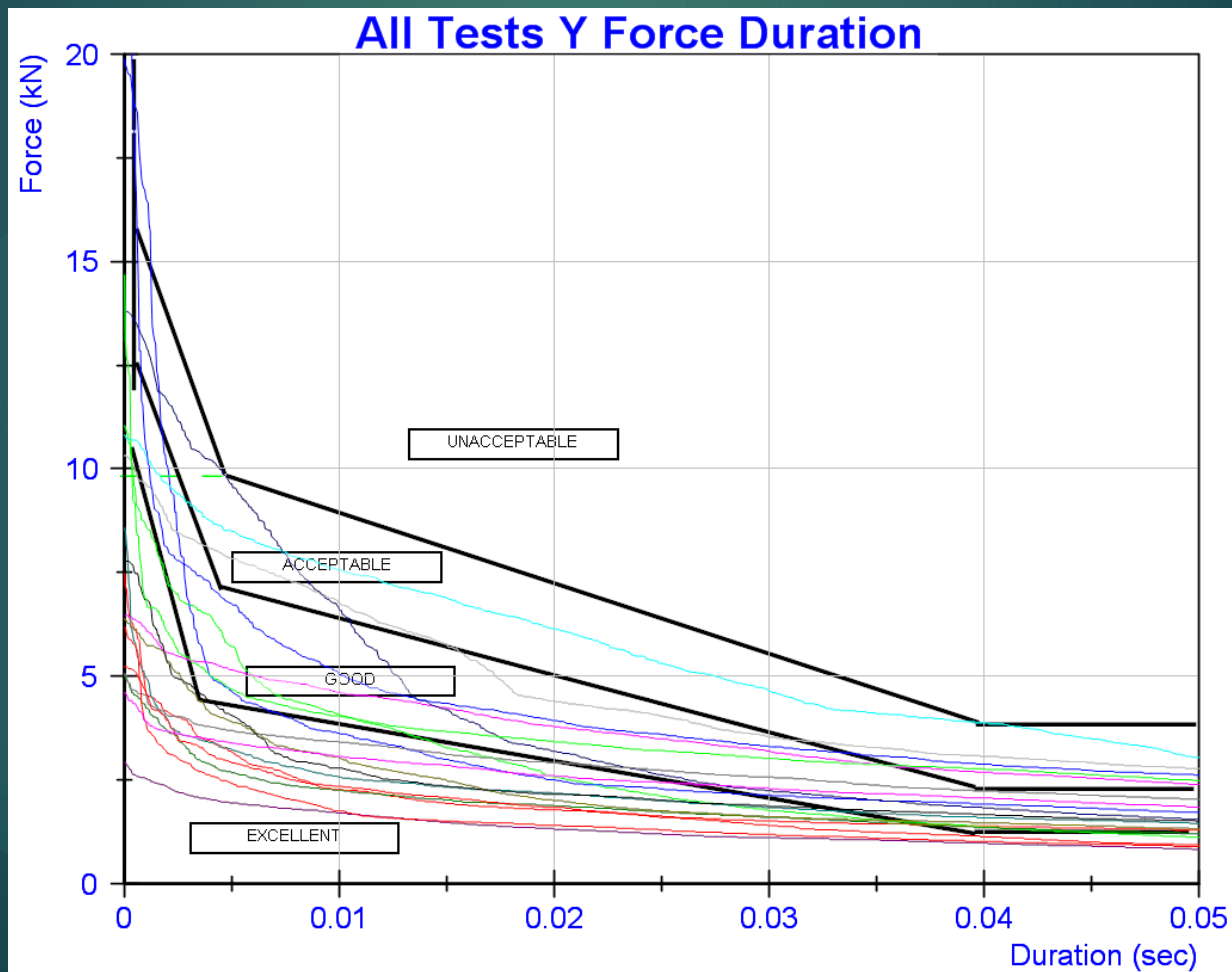


# Force Duration

## Proposed Criteria

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- ▶ Y-Axis Force Duration Rating Criteria (Example)



# Summary

- ▶ Impulse eliminates uncertainties in impactor displacement
- ▶ Impulse can be applied in all directions
- ▶ Impulse is directly related to aircraft momentum
- ▶ Impulse can be correlated to level of wing damage
- ▶ Force duration criteria can potentially provide a correlation between force levels and wing damage
- ▶ Rating criteria can be used for both impulse and force duration

# Recommendations

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- ▶ Replace energy criteria with impulse
- ▶ Research force duration criteria as a possible alternative to peak force